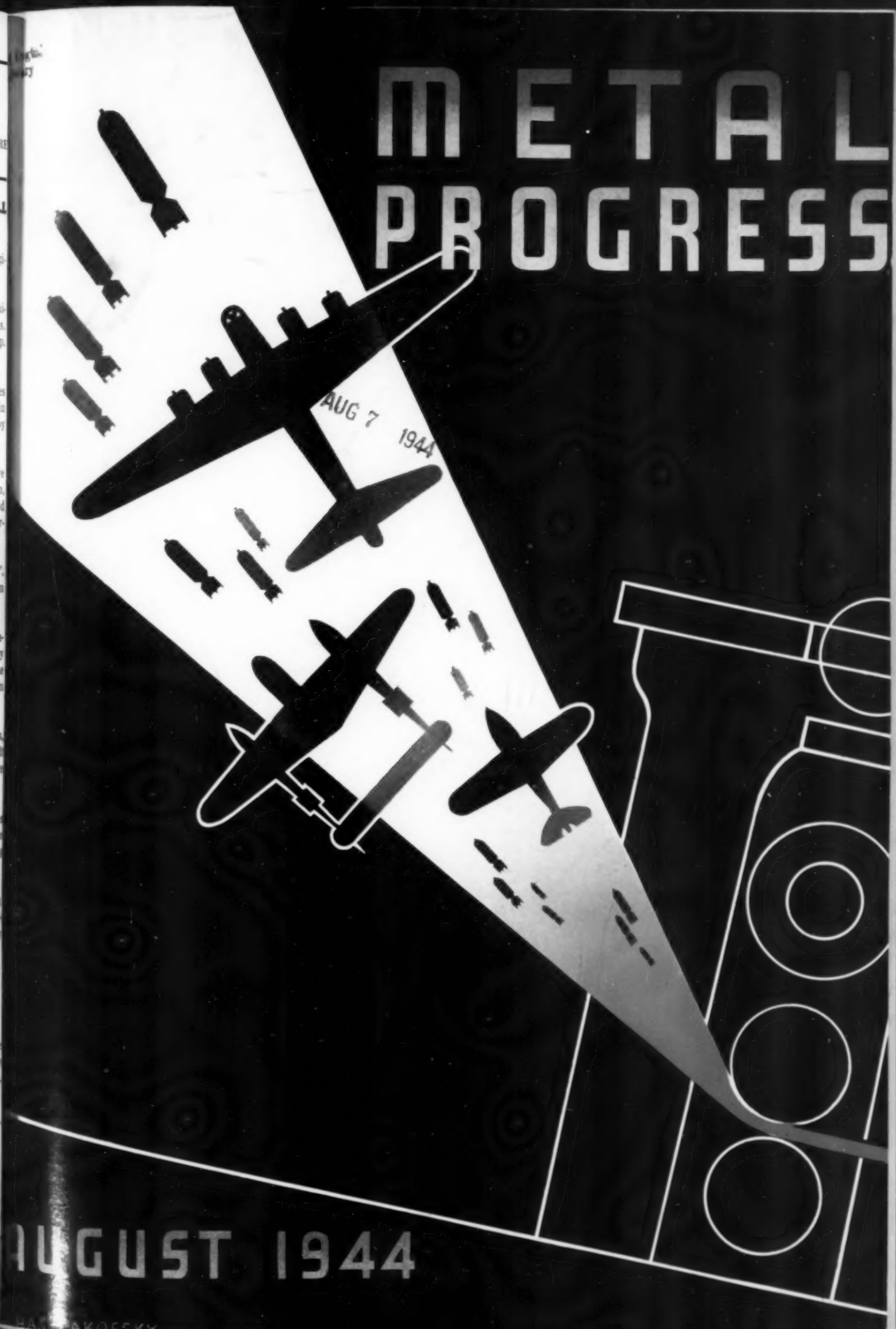
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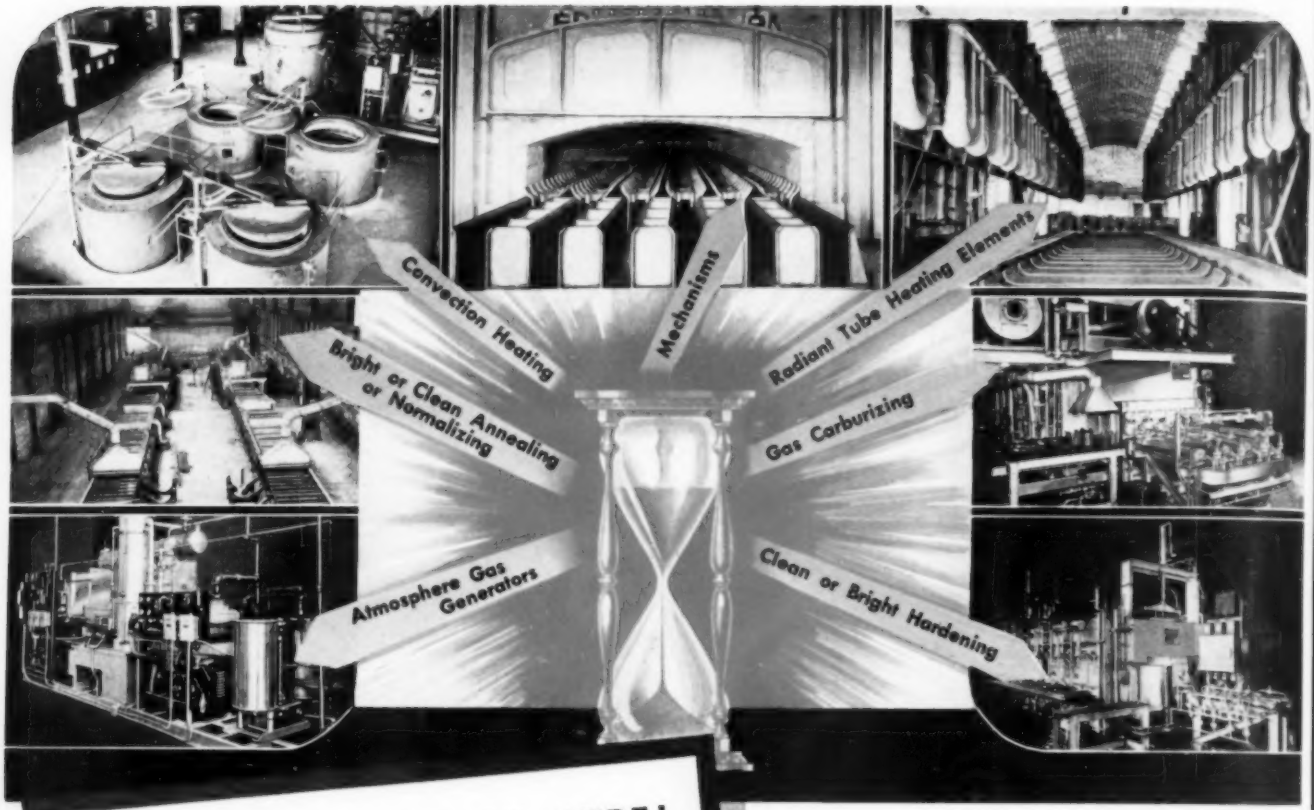

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Metal Progress

August 1944, Vol. 46, No. 2

Table of Contents

Effect of Structure and Composition on the Machinability of Copper Alloys 275
by D. K. Crampton

Rapid Hand Polishing of Micro Specimens 285
by Anton L. Schaeffler

John C. Garand, a Notable American 288
Biographical Note by E. C. McDowell

NE Steels in Oil Well Drilling Equipment 291
by Blaine B. Wescott

Bits and Pieces; Metallurgicus's Own Department
Identification of Brinell Balls; Suggestions by Harry P. Coats, Louis A. Carapella, R. W. S. Freeman, David Gross, and Max Herzog 295
Spotting Cobalt High Speed, by M. Robert Gross 295
A Film Dryer, by Earl J. Eckel 295
Sampling Molten Metals, by N. C. Fick 296
Unusual Type of Precipitation, by Charles Y. Clayton .. 297
Wrought Iron Pipe Replaces Copper Bus Bars, by J. A. Gerber 297
An Improved Method of Flow Line Etching for Nitralloy, by Martin Burg and George Weiss 297
Simple Die Converts Press Into an Upsetter, by W. C. Rowland 298

The Nitriding Process; Factors Influencing Ammonia Consumption 299
by C. V. Snell

S-Curves for Six NE Steels 304-B
Data Sheet, by U. S. Steel Corp. Research Laboratory

Critical Points, by the Editor
I Told You So 305
Production Line Manufacture of Ships 305
Mass Production of Aircraft 306
Victory on the Metal Front 306
Cans in Wartime 307
Research Pays the Nation 307

Incomplete Quenches

Timed Quenching 308
by Muir L. Frey

Martempering 309
by Benjamin F. Shepherd

Hot Quenching and Austempering 311
by H. J. Elmendorf

Personal Items 316, 318

Electrolytic Films Protect Magnesium 320
by N. Parkinson and J. W. Cuthbertson
Abstracted from "The Surface Protection of Magnesium Alloys", *Journal*, Institute of Metals, Vol. 69, 1943, p. 109.

Manufacturers' Literature 348

Index to Advertisers 398

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Effect of Structure and Composition on the

Machinability of Copper Alloys

By D. K. Crampton
Director of Research
Chase Brass & Copper Co.
Waterbury, Conn.

Copper alloys naturally subdivide into single phase alloys, binary alloys, and alloys containing fine dispersed inclusions. The latter may have machinability increased four-fold. Dr. Crampton shows how machinability is related to nature of dispersed phase, the composition of the alloy in major constituents, the previous cold work (the temper draw), and the nature of the cutting operation. He regards tests as interesting first approximations to what will actually be found in the shop.

WITH RESPECT TO MACHINABILITY, copper alloys are usually divided into three general groups. The first comprises "copper" — commercial metal — and the alpha solid solution alloys such as copper-zinc, copper-tin, copper-aluminum, copper-nickel and copper-silicon with no elements added to confer special machinability. The second group is made up of alloys sufficiently high in the principal alloying element to give a considerable amount of a second phase, ordinarily the beta solid solution. In other words, this second group includes the alpha plus beta brasses, tin bronzes, aluminum bronzes, and similar alloys. In the third group we have alloys from either of the two preceding groups to which an appreciable amount of some element has been added specifically to improve machining characteristics. With any amount approaching the optimum the result of this addition is so great as to overshadow completely any difference between one or two phases in the matrix, the basis of distinction between Groups I and II. For many years lead has been the outstanding and in fact almost the only element used to impart machinability, but others which more recently have been utilized, or offer possibilities along this line, are sulphur, selenium, tellurium and bismuth.

The three groups of alloys have been differentiated primarily by the type of chip, and this, in turn, is determined by the microstructure. In Fig. 1, page 276, are structures typical of the three groups and chips which would ordinarily be obtained from alloys having the corresponding structures. The micrograph at the lower left illustrates the structure ordinarily found in Group I alloys, which is seen to be homogeneous, consisting only of the typical twinned alpha grains. Of course it must be understood that there can be certain modifications of this structure such as variation in grain size and degree of distortion resulting from cold work, but these variations do not alter the fundamental requirement of homogeneity which characterizes these alloys and distinguishes them from the alloys classified in Groups II and III.

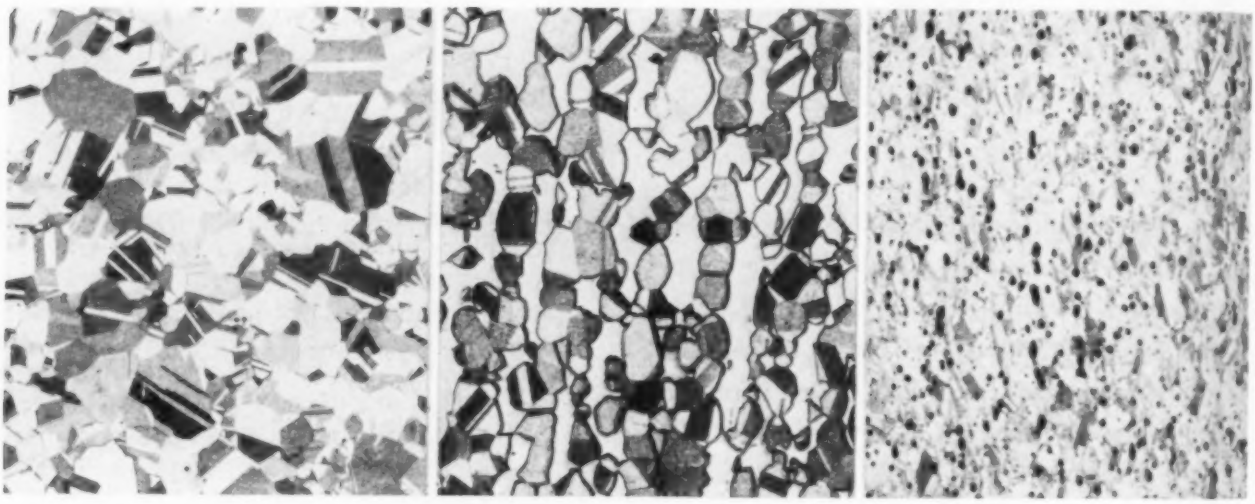
The central micrograph consisting of alpha and beta phases is typical of Group II alloys. In this figure the beta grains are the elongated irregularly shaped ones, and the alpha grains the polygonal ones. In this group, too, considerable deviation from the exact structure shown may be encountered while keeping to the essential condition of two and only two phases. These

Fig. 1 — Three Main Groups of Copper Alloys With Characteristic Microstructures and Chips

Group I — Alpha solid solution gives tough, springy shaving

Group II — Alpha-beta structure gives more brittle coils

Group III — Properly dispersed phase produces small chips



modifications need not be discussed at length.

A glance at the right hand micrograph discloses a very large number of particles of a dispersed phase, which in this instance happens to be free lead. The matrix is all alpha, but as stated previously, it could equally well be alpha plus beta, since differences otherwise attributable to variations in the matrix become relatively unimportant with so much lead present. Thus, the dispersed phase is the distinctive characteristic of the group.

In the upper photograph of the chips is shown, at left, a typical chip removed from an alloy of Group I. These are long, continuous, and frequently tightly curled like a miniature bundle of wire, but being very strong and tough act much as a coiled spring when opened out. They will withstand considerable distortion without breaking, even to the extent of bending flat back on themselves.

The chip illustrated in the center is typical of Group II alloys and is usually a fairly open coil or closely wound helix. However, the important difference between this chip and the preceding one is that it is relatively brittle and will withstand but little further distortion without breaking up into separate portions. This action is associated with the microstructure, the beta phase when cut being much more brittle than the alpha.

The chips at the right are quite typical of those removed from Type III alloys, very different in character from the other two. With most cutting tools and operations, the individual chips are small and extremely brittle. Due to this feature, chips free themselves very readily

Table I — Characteristics of Copper Alloys With Respect to Machinability

	Group I	Group II	Group III
Microstructure	Alpha	Alpha-beta	Dispersed phase
Type of chip	Very long and tough	Intermediate	Short and brittle
Machinability	Fair to poor	Good	Good to excellent
Strength	Fair to good	High	Fair to high
Ductility	High	Moderate	Low
Toughness	Very tough	Tough	Relatively brittle
Cold workability	Excellent	Good to poor	Good to poor
Hot workability	Fair	Excellent	Excellent to poor

from the tool or the machine and are obviously much better suited to rapid commercial work. The extreme brittleness of the chip is connected with the lead particles seen in the micrograph, but this feature will be dealt with in a more quantitative manner later in this discussion.

In Table I the principal characteristics of the alloys of the different groups are tabulated for ease of comparison. The type of chip has already been discussed. The machinability rating, which is usually based partly on laboratory tests and partly on commercial performance, is for Group I "fair to poor", for Group II "good", and for Group III "good to excellent". The variation in rating within Group I depends mainly on intrinsic alloy hardness, while in Group II it also varies with form and relative disposition of alpha and beta grains. But the variation in rating in Group III is almost entirely on the basis of *amount* of dispersed phase.

The strength of Group I alloys is usually only moderate, that of Group II much higher, while that of Group III may be either high or low, depending on the matrix. Ductility will in general run counter to strength, the strong alloys being less ductile, and vice versa. Likewise Group I alloys are usually very tough, Group II less tough and Group III alloys brittle.

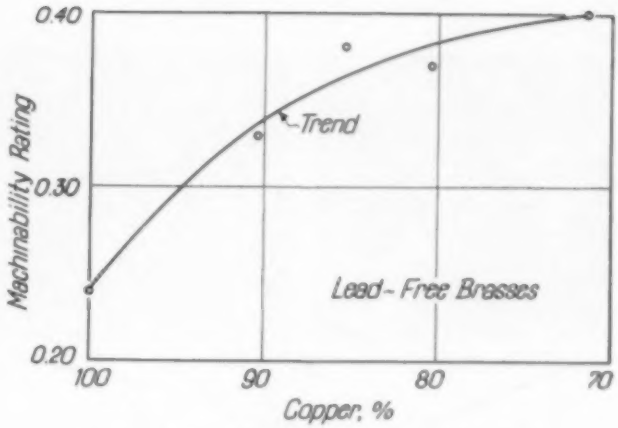


Fig. 3 — Machinability as Rated by Laboratory Work Increases With Zinc Content (Hardness) of the Alpha Brasses

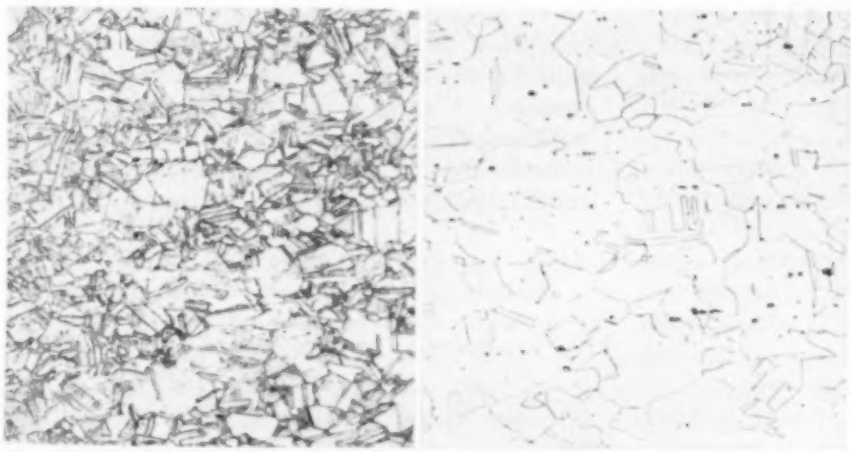


Fig. 2 — Oxygen-Free Copper (Left) and Tough Pitch Copper With Dispersion of Cuprous Oxide. (75 diameters)

Where machinability is the paramount consideration, it is obvious that only alloys of Group III would be used. However, there are frequent instances where, in addition to machinability, other properties are important, such as cold or hot workability, corrosion or season cracking resistance, conductivity, and color. It is seen that Group I alloys are rated excellent as to cold workability and fair for hot workability. Group II materials are good to poor with regard to cold workability but usually excellent from the standpoint of hot workability. In Group III the cold workability is good to poor, depending partly on whether the matrix is alpha or alpha plus beta, and also somewhat on the amount of lead or other dispersed phase. The hot workability may vary all the way from excellent to poor, again depending on the nature of the matrix, and both the amount and character of the dispersed phase. The latter feature will be discussed later.

Variation Within Groups — Although the main division into groups is on the basis of the types of structure just discussed, there are certain important variations within each of the three groups which merit discussion. We find in copper itself one important exception to the general rule for Group I alloys. There are really many types of copper commercially available, but on the basis of ease of cutting, these can be divided into tough pitch or oxygen-bearing coppers on the one hand, and deoxidized or oxygen-free coppers on the other. Structurally the latter types come strictly within the definition of Group I alloys — that is, they are of the homogeneous single phase type. (See Fig. 2.) As would be expected from the previous discussion, a metal with such a structure would be relatively difficult to machine and the chips would be long, curly, and very tough.

Tough pitch or oxygen-bearing coppers, on the other hand, are seen to contain cuprous

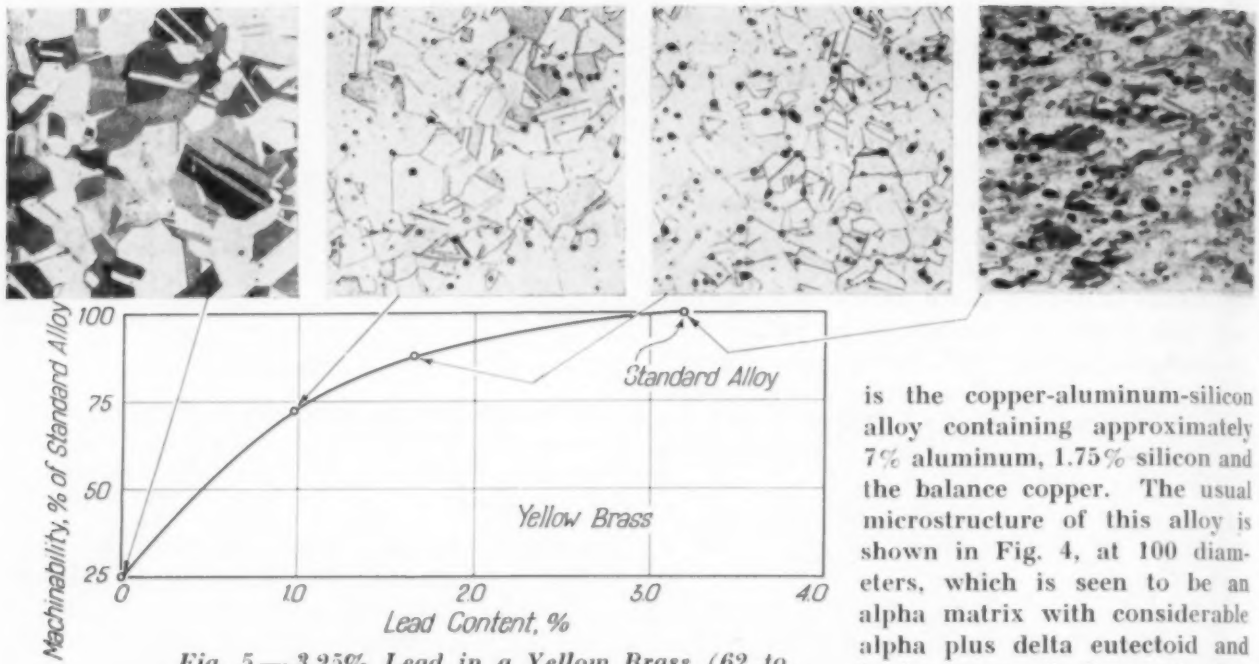


Fig. 5 — 3.25% Lead in a Yellow Brass (62 to 65% Cu) Increases Its Machinability Four-Fold

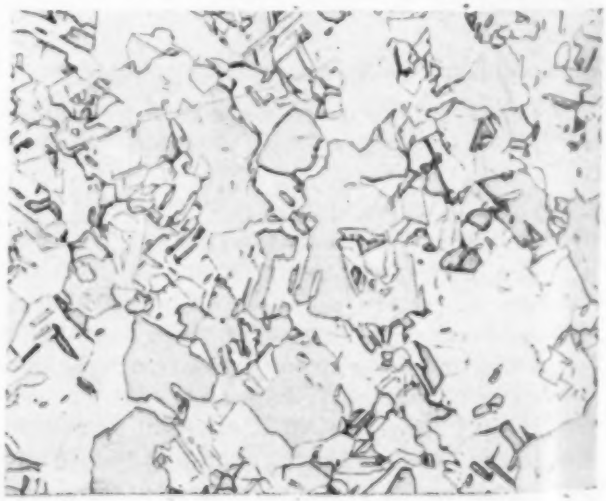
oxide as a finely divided dispersed phase, which functions somewhat as the lead particles of Group III machinable alloys, although from actual experience the degree of the effect is nowhere near as marked. Nevertheless, there is an appreciable difference in machinability, type of chip and surface finish obtainable with the two kinds of coppers, the tough pitch variety being noticeably better.

Another variation within main Group I comes from the progressive increase in alloy hardness in going from commercially pure copper to the saturated alpha solutions of copper-zinc, copper-tin, copper-aluminum, or others. This is well illustrated in the brasses, where (with a given treatment) the hardness increases more or less regularly with zinc content up to the limit of alpha solubility at around 37%. Figure 3 shows the result of certain laboratory tests on the machinability of alpha brasses, indicating that machinability increases from a rating of approximately 24 to approximately 40 with increase of zinc from 0 to 30%.

The machining properties of the Group II alloys are not outstanding, on the whole being more closely related to those of Group I than Group III. Their selection in preference to Group I alloys rests not so much on their better machinability as on their high strength and hot workability, most mill shapes being produced by extrusion, piercing or hot rolling. A rather outstanding alloy from the machining standpoint, is the copper-aluminum-silicon alloy containing approximately 7% aluminum, 1.75% silicon and the balance copper. The usual microstructure of this alloy is shown in Fig. 4, at 100 diameters, which is seen to be an alpha matrix with considerable alpha plus delta eutectoid and having unusually fine grain size. It is found that this alloy is much harder and much more brittle than most Group II alloys, and is much more readily machined. In this respect it approaches the performance of Group III alloys.

Specific Effect of Lead — Inasmuch as the Group III alloys are in general far more important from the machinability standpoint than either of the others, they warrant particular discussion. Figure 5 contains a graph showing machinability of brasses as a function of lead content, for high or yellow brasses containing approximately 62% to 65% of copper. Machin-

Fig. 4 — Microstructure of a Group II Alloy Containing 7% Al and 1.75% Si, Having Enough Alpha-Delta Eutectoid to Give it Machinability Approaching Group III Alloys



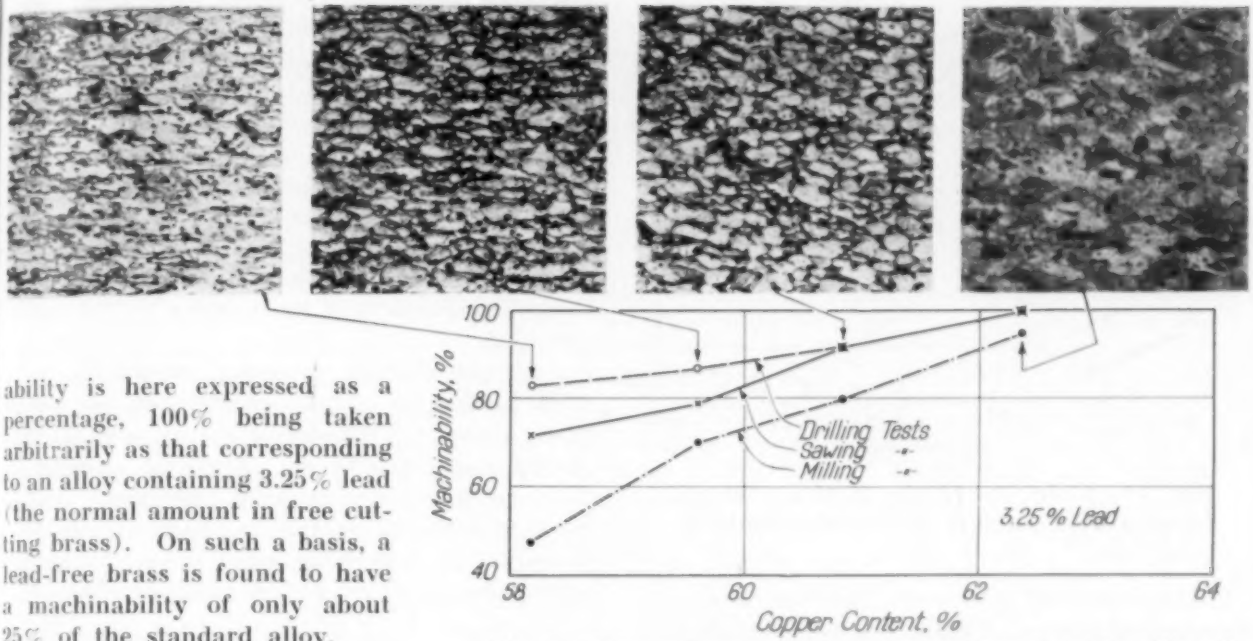


Fig. 6 — Lower Copper Contents Mean More Beta Constituent and Hence Better Machinability in Leaded Yellow Brass

ability is here expressed as a percentage, 100% being taken arbitrarily as that corresponding to an alloy containing 3.25% lead (the normal amount in free cutting brass). On such a basis, a lead-free brass is found to have a machinability of only about 25% of the standard alloy.

With addition of lead the ease of cutting improves rapidly at first and then at a diminishing rate. Extrapolation of the curve in Fig. 5 leads to the conclusion that an increase of lead beyond 3.25% is of little advantage. This accords with experience. In the upper part of this same figure are shown four photomicrographs of brasses having lead contents 0.005%, 0.97%, 1.66% and 3.20%. In the one at the left, there is no visible evidence of lead particles. Progressing to the right there is seen to be an increasing number of visible lead particles and the connection between the number of these and the machinability curve is fairly obvious.

The function of the lead particles is to increase the brittleness of the alloy and to cause the chip to break off readily and in short curls rather than in long stringers. Although decreased tool pressures and increased brittleness are noted with *any* lead additions, extremely short, brittle chips are obtained only when at least 2% lead is added to the brass. It is also to be understood that in brasses of any other range of copper content or in other alloys, much the same general relationship holds — that is, any addition of lead will markedly increase machinability, although the maximum lead content obtainable in other alloys may not be as high as 3 or 3.25%.

Reference has already been made to free cutting brass, which may be considered the standard free cutting alloy. The effect of variation of copper content from about 58% to about 62%, a range which could be used in alloys of this type, is shown in Fig. 6. The graphs in the lower part of the diagram result from certain tests in Chase Brass & Copper Co.'s Research Laboratories on alloys of four different copper contents, all containing about the same amount of lead, namely, 3.25%. Three different cutting tools and testing procedures were used, namely, drilling, hollow milling and sawing. Although in each instance a great increase in machinability with increase of copper content is apparent, the quantitative results do vary somewhat, the milling test showing the greatest variation.

In the upper part of the figure are shown four photomicrographs corresponding to the individual alloys used in the tests, the principal difference obviously being in the amount of beta present. As would be expected, with the lowest copper there is considerable beta which progressively decreases until at 62% copper there is apparently none. Doubtless the improvement in machinability is due to this factor rather than to the variation in copper itself. (Incidentally, it might be pointed out that European practice favors a copper content around 59 to 60%, whereas in this country it is more common to use 61.5 or 62.0% copper which, on the basis of tests as here illustrated, would appear to be justified.) Among other things these tests perhaps illustrate how irrational it is to accept too literally the results of any one method or a single set of test data. Probably all short-time machinability tests should be regarded as interesting first approximations rather than as final criteria.

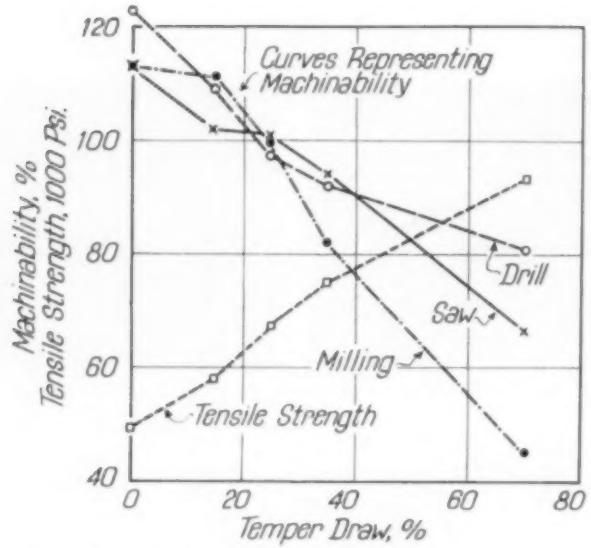


Fig. 7 — Cold Work in Temper Draw Impairs Machinability of Free-Cutting Brass

The effect of cold work hardness has been referred to briefly. Figure 7 shows the effect of degree of final draw on the machinability characteristics of a typical free-cutting brass containing 62.34% copper and 3.54% lead, balance zinc. A curve is also included showing the increase in tensile strength of the alloy as a function of degree of cold drawing. The same three machinability tests were used as previously, but here the individual results are in somewhat better agreement. It is concluded that machinability of leaded brass is drastically reduced with increase of degree of draw (cold work) and with increase of tensile strength resulting therefrom. This is quite different from the reported properties of steel used for "screw machine stock", a low carbon analysis whose microstructure is substantially soft, ductile ferrite, embrittled with a dispersion of manganese sulphide inclusions; in spite of obvious similarity in metallographic constitution, the machinability of steel screw stock is very materially *increased* by moderate cold work corresponding to the temper draw here described for the leaded brass.

In one sense, however, these particular results for reductions in machinability in brass after cold drawing up to 70% are of more academic than practical interest, since for most sizes it is impractical to give leaded brass more than about 25% cold reduction.

The adverse effect of increasing cold work on machinability is also shown clearly in some experiments where the time it takes a ¼-in. drill to penetrate 1 in. is noted, the specimens varying in tensile strength by virtue of increasing the degree of final draw. In these tests a high speed steel drill was run at 1150 r.p.m. with an axial load of 40 lb., and the brass rod was held in the pendulum head of a torsion testing machine. The relationship between drilling time and tensile strength is almost linear, increasing from about 34 sec. to penetrate 1 in. in a rod of 60,000 psi. tensile strength, to about 48 sec. to penetrate 1 in. in a rod of 83,000 psi. In this particular investigation, the front and back ends of a very long extruded rod were examined, and results for these two portions show little difference, the conclusion being reached that machinability is practically independent of the position in the rod as extruded.

Simple drilling or other laboratory tests, while indicative of performance, do not necessarily always tell the complete story as to machinability and results so obtained should be interpreted and applied with judgment. One of the difficulties in interpreting such data is illustrated in Fig. 8 showing four curves representing torque developed by a ¼-in. drill as affected by

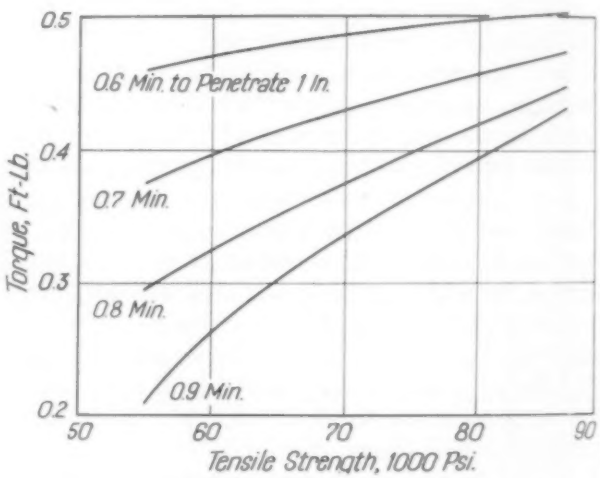


Fig. 8 — Machinability, as Measured by Drilling Time, Varies With Torque on Drill and Tensile Strength (Free-Cutting Brass Strengthened by Cold Work)

the strength of the brass rod being drilled. The work was typical free-cutting brass containing 62.8% copper, 3.29% lead, remainder zinc. The general conditions of test were similar to those described for the preceding experiment. Four different tempers were used, and the axial load on the drill varied over a considerable range. The individual curves are derived ones corresponding to four different times required for penetrating exactly 1 in. In all cases the torque increases with strength, but the rate of increase varies inversely with the time required for 1-in. penetration. Were we to consider only the lower curve, we might conclude the high strength rod

had a machinability only about one-half that of the softest rod. However, considering the upper curve, the difference due to temper is only on the order of 15%. It is thus necessary to know all conditions of test before final conclusions can be drawn. Perhaps one of the most significant indications of this particular test is that if high enough pressures and speeds were used — and the tool could stand these — the differences due to temper of the free-cutting brass become insignificantly small.

The significance of the lead particle in breaking the chip is perhaps not always appreciated. This may be due partly to the fact that we ordinarily visualize the structure of the work on the basis of photomicrographs commonly taken at from 50 to 75 times or perhaps an even greater magnification, whereas we think of the tool in terms of its actual size. Were we to magnify the tool to the same degree as the photomicrograph of the structure of metal being cut, the whole action might be visualized quite differently. In Fig. 9 an attempt is made to show this. There is the typical structure of free cutting brass rod enlarged 50 times, showing normal lead particle size and distribution. There is then shown in outline the point of a drill entering this material. The drill is assumed to be actually $\frac{1}{16}$ in. diameter and the original line diagram is magnified 50 times to correspond with the micrograph. The dotted line shows the position of the drill after one revolution with a feed of 0.004 in., a normal amount for such a diameter.

The striking thing in this view is the very large number of lead particles in the cross section of metal removed. Looked at in this way, it is easy to see why even the relatively small percentage of lead is so effective. Had a larger diameter drill been drawn to the same scale an even more striking picture would result.

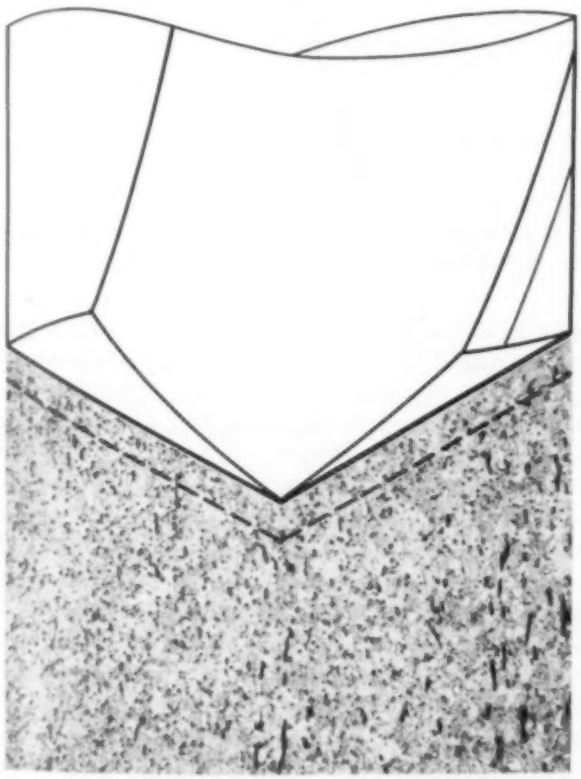


Fig. 9 — Some 150,000 Lead Particles Are Contained in the Brass Removed in One Revolution of a $\frac{1}{16}$-In. Drill

Table II — Number of Lead Particles in Metal Removed in One Revolution When Drilling Free-Cutting Brass

Diameter of Drill	Feed Per Revolution	Volume Removed Per Revolution	Lead Particles in Volume Removed
$\frac{1}{32}$ in.	0.002 in.	0.0000015 cu.in.	18,000
$\frac{1}{8}$	0.004	0.000012	150,000
$\frac{1}{8}$	0.010	0.00012	1,500,000
$\frac{1}{4}$	0.015	0.00074	9,000,000

A tabulation of the number of lead particles in the volume of metal removed in one revolution of a drill, assuming normal conditions for drilling of free-cutting brass, is given in Table II. In making these calculations, the basis used was the average number of lead particles found by actual count in typical samples of this alloy — which incidentally average about 12 billion per cu.in.! Even with a $\frac{1}{32}$-in. diameter drill and a feed of only 0.002 in. per revolution, the total number of lead particles is about 18,000. The figure jumps up to 9,000,000 for a $\frac{1}{4}$-in. drill.

A few more figures, also giving a graphic idea of the number of lead particles involved in metal cutting, are computed for free-cutting brass assuming an ordinary lathe operation under conditions which might normally be used. The final figure shown is the number of lead particles in a *cross-section area* of the chip being cut, not the volume of metal cut. For a roughing cut of $\frac{1}{4}$-in.

	Roughing Cut	Fine Finishing Cut
Depth of cut	$\frac{1}{4}$ in.	$\frac{1}{32}$ in.
Feed	0.040 in.	0.010 in.
Area of chip	0.010 sq.in.	0.0003 sq.in.
Number of lead particles in cross section	52,000	1,600

depth and 0.040-in. feed, it is seen that some 52,000 lead particles are involved in the *area* subject to shear. Likewise, with a finishing cut of $\frac{1}{32}$-in.

depth and 0.010-in. feed, there are 1600 particles involved. It should be apparent that wide variations in actual size and distribution of lead particles could be experienced and still have an enormous number of individual particles involved in chip breakage in any one cutting operation and at any one instant.

Leaded Bronze — Considerable has been said about cutting of free cutting brass rod but it is quite impossible in a short space of time to deal with each machinable alloy on an extended basis. One other alloy which is used in considerable quantities will, however, be mentioned in some detail. This is leaded commercial bronze containing nominally about 89% copper, 9% zinc, 2% lead, an excellent alloy whose machinability approaches that of free-cutting brass. We studied, among other things, the effect of additions of three different metals to this alloy, and also of variation in temper or degree of cold work. Figure 10 shows the effect on machinability of increasing tin content up to about 1.8%. Drilling, sawing and milling tests were carried out; there is reasonably good agreement between them, and the heavy curve which is a mean of the three individual results can be taken as a fairly accurate indication of the effect of tin on machinability. On this basis it can be concluded that tin is definitely detrimental to the machinability of leaded bronze.

Similar tests with varying iron additions up to 1.6% gave a rather poorer concordance. Sawing tests showed little change, although milling tests definitely deteriorated with increasing iron. The conclusion is that increasing iron lowers the machinability of the alloy, at a somewhat less rate than does tin (135% for no iron and 120% for 1.6% iron). It is probable this is an indirect result of alloy hardening.

Similar tests show that increasing the amount of nickel up to about 0.8% does not affect the machinability of leaded bronze appreciably. This is interesting as it is known nickel does not increase strength and hardness to the same degree as do iron and tin.

Finally, we have Fig. 11 showing the effect of the degree of final cold draw on machinability of leaded commercial bronze, again using the same three tests. While there is an appreciable lowering of machinability due to increased degree of cold draw, this does not seem to be as drastic as was the case with free-cutting brass rod shown in Fig. 7. Possibly this is because of the known lower rate of work hardening possessed by the leaded bronze.

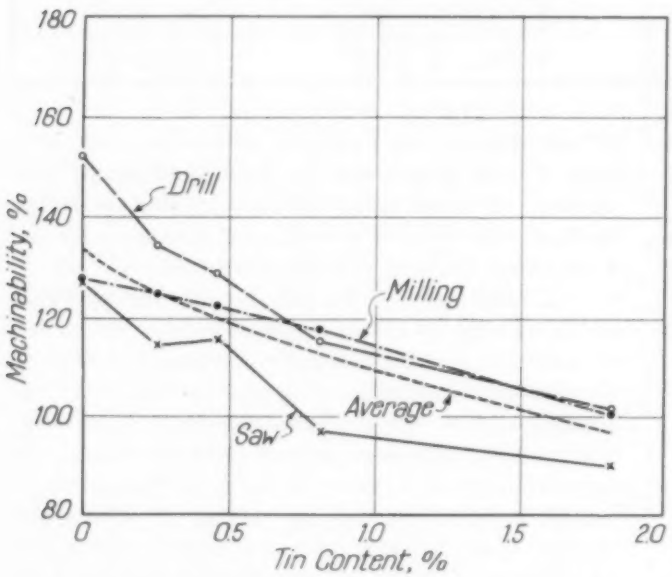


Fig. 10 — Tin, Added To Leaded Bronze, Definitely Impairs Machinability

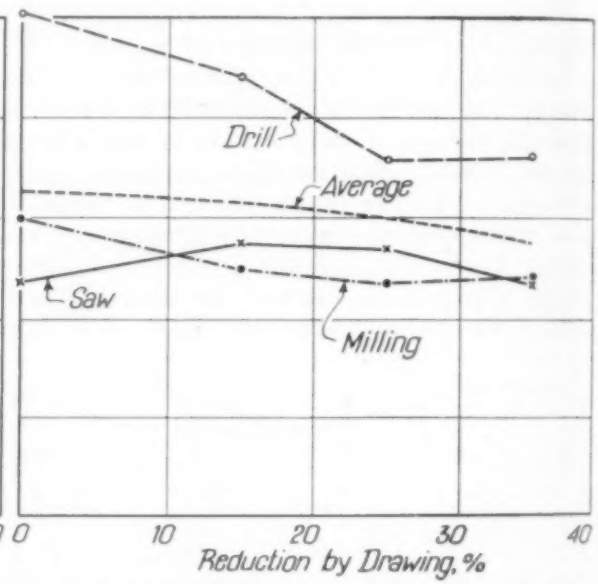


Fig. 11 — Reduction on Temper Draw Has Slight Effect on Machinability, Except in Milling Operations

Other Addition Elements — Reference was made earlier to the fact that in relatively recent years the elements sulphur, selenium and tellurium have been demonstrated to have the same general effect as lead on the machinability of copper alloys. Alloys containing tellurium have been commercialized and in certain respects have been found superior to the conventional leaded alloys. Microstructure of an alloy containing approximately 99.5% copper and 0.5% tellurium in the condition as cast has typical large grains with a considerable amount of dispersed phase, a copper telluride of the formula Cu_2Te. Figure

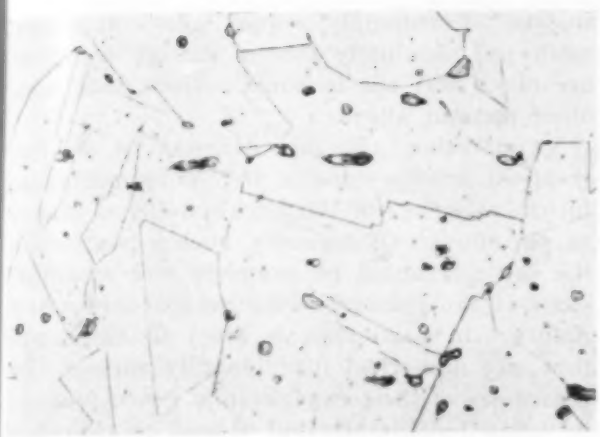


Fig. 12 — Copper With 0.5% Tellurium, Cold Worked and Annealed. Copper telluride particles are somewhat elongated

12 shows this alloy after it has been cold worked and annealed. The individual copper telluride particles are seen to be somewhat elongated in the direction of working. As a matter of fact, such alloys quite commonly have even more tenuously elongated particles than here shown. Such an alloy is approximately as machinable as free-cutting brass, is quite free of any tendency toward fire cracking, and lends itself quite well to hot forging operations. In all these respects it is clearly superior to a copper-lead alloy with 0.5% lead.

Relation between machinability and amount of sulphur, selenium and tellurium added to copper is shown in Fig. 13, taken from the work of Cyril S. Smith. The basis of appraisal is the number of turns of a drill under constant load required to penetrate ¼ in. into the alloy indicated. For all three elements the number of turns required drops quite abruptly with small additions and then less slowly as increased amounts are used. There appears to be relatively little advantage in more than 0.5% of any of these elements.

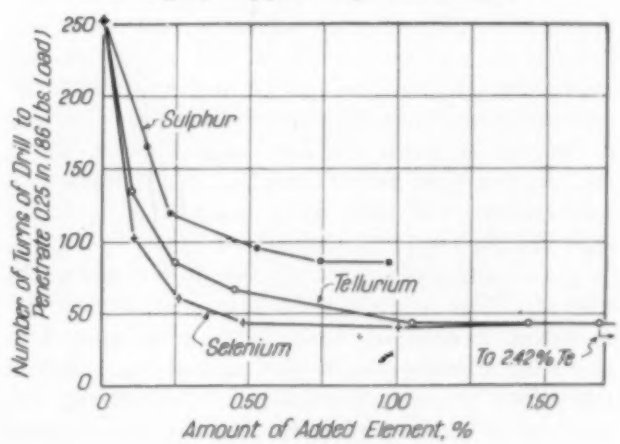
It has been found that tellurium has the same general effect on improving machinability of various alpha alloys as it has with copper. In some tests made in the Chase laboratories, the effect of tellurium on machinability of alpha phase alloys paralleled that shown in Fig. 13. However, its effect on alpha plus beta brasses is quite different. When tellurium is added to muntz metal, an alloy of approximately 60% copper, 40% zinc, no improvement whatever results up to a total tellurium content of approximately 1.8%, which was the highest amount used. Conceivably in this alloy the dispersed phase is not the simple copper telluride, as in other alloys described, but may be a more complex compound containing considerable zinc. In any event, it is obvious that muntz metal does constitute an exception to an otherwise general rule.

The behavior of muntz metal to which tellurium has been added raises a very pertinent question as to whether *every* dispersed phase necessarily improves the cutting properties of an alloy. Going back momentarily to the leaded alloys which have for years been the standard free-cutting ones, it should be noted that lead particles themselves, in addition to being relatively small and well dispersed, are quite soft. While they contribute brittleness to the alloy and aid in breaking up of the chips, they offer no particular resistance to the cutting edge of a tool. In fact, there is some indication that lead particles may even act as a lubricant under the high tool pressure.

In the case of copper telluride (the phase contributing machinability in alloys containing tellurium) there is evidence the telluride itself is harder and more abrasive than lead, although apparently it is of very low strength and very brittle. The chip breaking action is apparently much the same but wear on tools is greater. Hard carbide tipped tools are commonly used with the tellurium alloys; under such conditions they give excellent performance.

If now we consider the effect of a very hard dispersed phase a different situation may well result. The hard particles may or may not have a specific embrittling effect, the same as lead or copper telluride, but should they come in contact with the actual cutting edge of a tool, they might cause considerable wear and dulling, as well as minute nicks. These in turn mean the generation of extra heat and inability to maintain finish or tolerances — in short, poor machinability. Such very hard dispersed phases are frequently

Fig. 13 — Effect of Sulphur, Tellurium and Selenium on Machinability of Copper. (Cyril S. Smith)



encountered, as for instance in manganese bronzes (which are in reality special brasses containing small but important percentages of such elements as manganese, iron, tin, aluminum or silicon). The matrix structure is always alpha plus beta but frequently there are dispersed particles of hard phases, the exact composition of which is not always known. Figure 14 represents a typical manganese bronze with such hard particles, an alloy known to be quite hard and relatively difficult to machine.

Figure 15 also shows a structure sometimes encountered in manganese bronze, where a third hard phase is present as discontinuous intercrystalline films, as well as dispersed spheroidized particles. In such a structure, the tool will rapidly dull, perhaps even more rapidly than when cutting the preceding structure.

It seems not out of place to make brief reference to metallic and non-metallic inclusions not present as normal phases of the alloys considered. Such inclusions, which may be quite large as compared to the dispersed phase particles discussed up to now, can have a serious effect on cutting tools. A single such particle if large and hard might well nick the cutting edge so badly that the tool must be reground.

An example of such an inclusion is shown in Fig. 16. The alloy is free-cutting brass and the inclusion is certainly quite large as compared to the lead particles seen throughout the matrix. Obviously if such a particle should strike the edge of a cutting tool, it might cause serious trouble. Fortunately, copper alloys in general, while not absolutely free of foreign inclusions, are much less apt to contain these than many other metallic alloys.

Conclusion — In this discussion we have reviewed briefly some of the more outstanding factors entering into the machinability of wrought copper alloys. Of necessity, such a treatment of the subject cannot be complete and admittedly some of the points covered are controversial in nature. In particular, it must be emphasized that any numerical machinability ratings used, regardless of their experimental basis, must not be taken too literally but should be considered simply as indicative of relative performance as between different materials or varying treatments.

Perhaps others in preparing discussions of this kind have had generally similar experience to mine: At the start, with a wealth of data available, there is the impression that one knows much about the subject. As this is boiled down into reasonably brief form and critically examined, more and more questions arise about the validity of certain assumptions, or perhaps concerning the significance of various experimental data. Finally there comes the realization of how little is actually known about the fundamental phenomena involved, or even the practical significance of the experimental results. However, such data as have been presented do have some reasonable foundation and, if nothing more, they should serve as a basis for profitable thought and discussion.

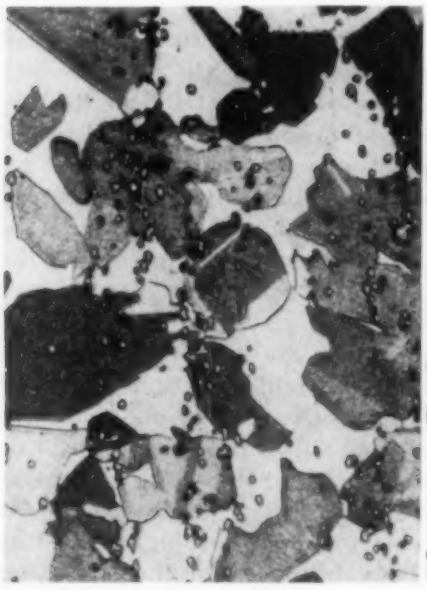


Fig. 14 — Dispersed Particles in a Manganese Bronze, Difficultly Machinable

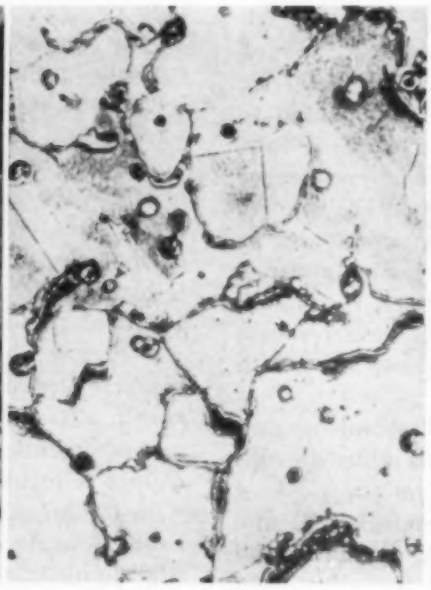


Fig. 15 — Manganese Bronze With Third Hard Phase as Intercrystalline Films

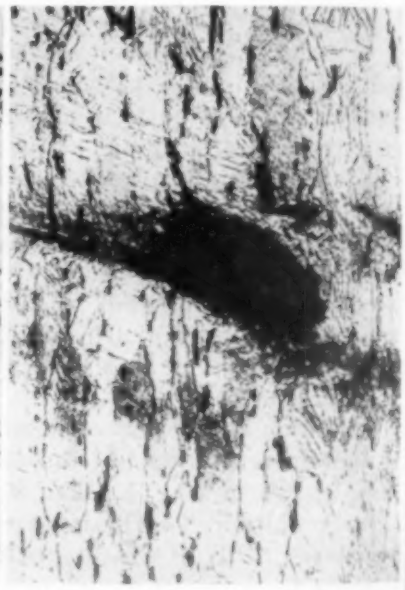


Fig. 16 — Non-Metallic Inclusion in Free-Cutting Brass, Much Larger Than the Lead Particles

Rapid Hand Polishing of Micro Specimens

By Anton L. Schaeffler
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The technique described is for production control of hard alloys, and utilizes emery papers, wax lap, and "Gamal on Gamal." The latter is a trade expression describing an abrasive containing alumina in gamma crystallographic modification, and a cloth with especially fine, close pile.

MANY are the methods and variants used for polishing metallographic specimens. Perhaps no universal "best" method will ever be found, because of the great variety of alloys that are prepared, and because of the numerous types of information that may be sought. However, since polishing may be a time consuming operation, it is desirable to seek speedy methods — and this is especially true for production control laboratories. For this reason the method given below will be of interest to those who must make routine investigations for inclusions, although we are also using it for the strictly "research" type of work. Specimens which are free from all scratches can be prepared in seven minutes by using three grades of emery papers, a wax lap, and a final polish with "gamal". Procedure is as follows:

Rough Polish — After mounting in bakelite or other plastic (if the specimen is small), it is given a rough polish on three grades of emery papers, No. 1, 1/0 and 2/0, in the usual manner. The specimen is then turned 90° and repolished on a worn spot of 2/0 paper using light pressure. This added operation expedites subsequent polishing on the wax lap. If a very flat specimen, clear to the edge, is desired, the rough polish should be done on a lead lap. Figure 1 shows the finish obtained from 2/0 emery paper.

Wax Lap Preparation — Two types of waxes were tried on the lap, namely, wax from hydrofluoric acid bottles, and parowax. The parowax proved to be the more satisfactory, which could doubtless be attributed to its demonstrably greater hardness.

The wheel to be used should have a cloth securely stretched and fastened over it, to assure good adherence of the wax layer. A paper dam is placed around the wheel and, after leveling, the wax is poured to a depth of ½ to ¾ in. (This takes about three bars of parowax). After the wax has solidified the dam is removed and the

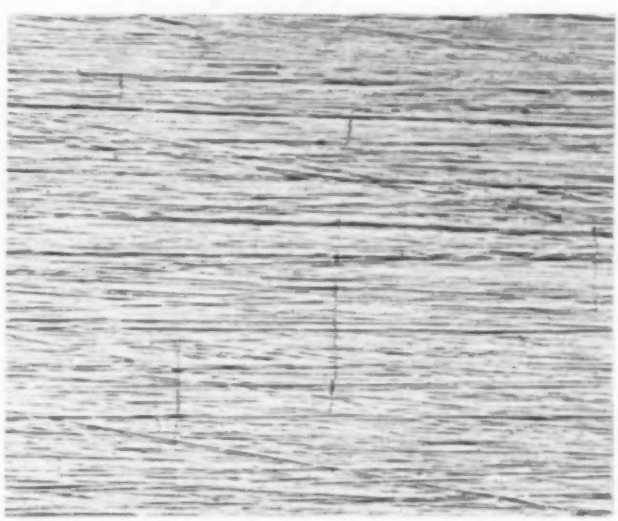

Fig. 1 — S.A.E. 4340 Steel After a Rough Polish on 2/0 Emery Paper. Magnification 100 diameters. The wavy lines at right angles to the scratches are strings of inclusions

wheel is trued by revolving at a high speed and removing the excess wax from the sides and top with a straight edge. Spiral grooves, $\frac{1}{16}$ in. deep, are then cut into the flat surface of the wax using a piece of saw blade having very coarse teeth. The cut is started at the outside of the wheel and, traveling radially, is ended at the center of the lap. These grooves retain the polishing solution, thereby increasing its cutting action on the specimen.

Polishing Solution for Wax Lap — The wax lap solution consists of 100 cc. water, 2 teaspoons levigated alumina, and 2 cc. liquid soap (or enough to allow the solution to wet the wax). This should be thoroughly mixed (not ground) and decanted into a wash bottle immediately. This leaves behind the very coarse particles which would scratch the specimen too deeply. (Grinding would lose the abrasiveness of the particles.) It is better to prepare only the above amount at one time — or at most, twice the amount. If more is prepared, the alumina tends to cake upon standing.

Polishing on the Wax Lap — The recommended wheel speed is 600 rpm. The specimen should be given a fast radial motion with no side sway. If grooves appear on the specimen, the radial motion is not fast enough. Heavy pressure can be applied to the specimen, and the wheel should be well supplied with solution. After polishing for 15 sec. the specimen should be turned 180° and polishing continued to completion. The time of the entire lapping operation should be about 45 sec., once the lap has been "broken in" with work on one or two specimens. If the lap tends to drag and a wax film forms on the specimen, either the lap has not yet been "broken in", or the wheel speed is too slow. If the wheel becomes caked with alumina, the top surface should be shaved off. Properly cared for, the wax does not need renewal until 500 or 600 specimens have been polished. A specimen finished on the wax lap is shown in Fig. 2.

Final Polishing is done on "gamal" cloth using "gamal" solution with a wheel speed of 200 to 260 rpm. The best concentration of solution was found to be 1 oz. of "gamal concentrate" to 20 oz. of distilled water. The solution recommended by Fisher Scientific Co. is more dilute, but it was found that this lengthens the polishing time and causes the specimen to be relief polished. The solution is applied to the outer portion of the wheel, leaving the center clean to remove any remaining surface film from the

Fig. 2 — S.A.E. 4340 Steel After Wax Lap Polish. Magnification 100 diameters

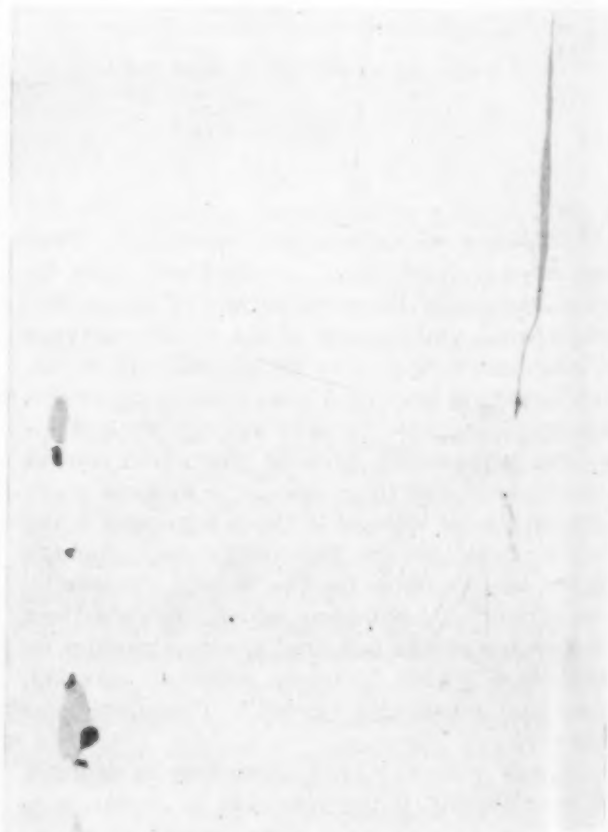

Fig. 3 — S.A.E. 4340 Steel After Gamal Polish. Not etched; magnification 1000 diameters

specimen. The specimen is held in one position, utilizing side sway motion and slight pressure. Only one application of solution per specimen or for every two specimens is required. While the present price of "gamal" concentrate seems high ($1.40 per oz.) the cost of the solution amounts to less than ½¢ per specimen, if used as recommended. The special cloth costs 80¢ for a 10 x 10-in. piece. Finishing some 300 specimens has not visibly worn it.

Samples of the work, unetched, photographed at 1000 diameters, are shown in Fig. 3, 4 and 5.

Nature of Gamal and Gamal Cloth — "Gamal" is a trade name, coined from "gamma alumina", which is its principal ingredient, according to the manufacturer, Fisher Scientific Co. (Spectrographically, the powder also shows strong lines of silicon.) The following excerpts from Fisher's publication, *The Laboratory* (Vol. 13, No. 5) refer to that company's recommendation of the polishing team, "Gamal on Gamal":

"Alumina, or aluminum oxide, exists in nature or it can be produced in three different forms — alpha, beta and gamma. These differ only in their physical structure and properties. Gamal has a different refractive index from either alpha or beta alumina and, most important in its new application, has a different crystallographic structure, a different degree of hardness and a different particle size. All of these physical properties, peculiar to Gamal, particularly suit it for application as a metallographic polishing material.

"The crystallographic form of Gamal is seen under the microscope to be plate-like, with the length and breadth of its crystals many times their thickness. These plates are extremely hard yet they are so brittle that pressure on the polishing cloth causes them to break into particles shaped like minute cubes....

"The new cloth has a firm backing of finely woven material on which are held innumerable synthetic 'bristles' that make a nap or pile. These fibers act much as a tooth brush does when tooth paste is applied to the teeth — it supports the particles of Gamal while the specimen is held against the revolving cloth on the metallographic polisher. The greater number of these soft synthetic fibers, their even spacing and their upright position are distinctive advantages of Gamal cloth as compared with the helter-skelter arrangement and relative scarcity of fibers on the surface of other polishing cloths."

Unetched Samples Showing Retention of Non-Metallics. Magnification 1000 Diameters

Fig. 4 — Low Carbon Enameling Iron

Fig. 5 — "Zenite" Cast Iron

A Notable American

John C. Garand

Recipient of A.S.M. Medal and Scroll

ON MARCH 28, 1944, Secretary of State Cordell Hull, on behalf of the United States Government, presented the first civilian Medal of Honor to John C. Garand for "exceptionally meritorious service" to his country. That service was, as everyone knows, the designing and successful development of the semi-automatic rifle which the Army and Marine Corps adopted in 1939 as the standard infantry weapon, superseding the bolt-action Springfield rifle, model 1903. The new Medal of Honor for civilians is the equivalent of the Congressional Medal of Honor awarded in rare and exceptional cases to soldiers, sailors and airmen, and the only other civilian to have received one, at this writing, is the physicist who developed radar, Dr. Albert White Taylor of the Naval Research Laboratory. He received his award at the same ceremony with Garand, and it is noteworthy that both earned their reward only after long years of hard and unheralded work, Taylor having started his radar work in 1922 and Garand having begun the semi-automatic rifle in 1920.

Garand, who is chief ordnance designer and assistant works manager of the government arsenal at Springfield, Mass., has been working for the government since 1917, and in that time has developed a machine gun, two machine rifles, and three semi-automatic rifles of which the present Garand rifle — officially known as the "U. S. Rifle, Calibre .30, M-1" — is his crowning achievement. In addition, he has designed a score of special machines for gun manufacture, and planned many new methods of speeding up production at the arsenal.

Long before the government got around to giving Garand his Medal of Honor, his professional confreres had recognized his unique engineering talent, and he has been the recipient of several awards, among them the Holley Medal of the American Society of Mechanical Engineers, the Rice Medal of the American Ordnance Society, the Lord & Taylor American Design Medal, and the Special Medal and Scroll of the American Society for Metals. Garand, who is a member of the Springfield chapter, was given the Society's special award at its 1942 annual dinner "in recognition of his outstanding contribution to the defense of the nation".

Although he began designing his semi-automatic rifle in 1920, it took 16 years before the Army decided he had a practicable weapon and gave him the go-ahead signal. In the next three years, when the Army in 1939 finally approved and adopted the M-1 rifle, it was given the most thorough tests and trials possible by the Ordnance Department. In addition to studies at Aberdeen proving ground, models were sent to various Army posts throughout the country and tried out by infantrymen under the most severe field conditions, sometimes being buried in mud for a few days or left in water all night. When the Garand was finally adopted it had had all of its "bugs" corrected and, as far as the Army was concerned, it was a dream rifle. Nevertheless, a great storm of criticism arose from rival designers and various groups, most of whom were apparently unaware of the long and rigorous tests the M-1 had weathered before it was accepted. So great was this hubbub, in which *Life* and *Time* magazines, and the journal of the National Rifle Association — a civilian organization — took a leading part, that there was considerable difficulty in Congress with an appropriation for $2,000,000 in 1941 for quantity production. It was not until the Battle of Bataan in 1942 that the Garand was tested in actual combat, and it performed so well that all the criticism stopped completely. General MacArthur, himself, went out of his way to praise the weapon's efficiency, and it is now generally agreed that the M-1 is the finest infantry rifle in use in any army in the world today, and is the greatest advance in design of any military rifle since the advent of the Springfield.

Its advantages over the latter are easily seen in the following comparison: It can be fired by an expert at the rate of more than 100 aimed shots a minute, or five times as fast as the hand-operated, bolt-action Springfield, and an ordinary rifleman can fire 30 aimed shots a minute with it. It takes a clip of eight rounds as against the older rifle's five and doesn't kick as hard. It has only 73 parts — about 35 fewer than the Springfield, and weighs about the same (9 lb.).

THROUGHOUT all this uproar over his rifle, and the acclaim that its success has brought to him, John Garand has said very little and remained as affable and hard working as ever. He took no part in the controversy, and has been characteristically modest and shy amid the kudos and medals that have come to him since his fame has spread. He is a short, muscular man with a strong square face, dark unruly hair, and a noticeable French accent. Of French-Canadian

stock, he was born on a Canadian farm near the village of St. Remi not far from Montreal about 57 years ago and was eighth in a family of 12. He and his brothers became crack shots while still very young by practicing with guns which members of a nearby gun club stored at the Garand farm-house between meets; one of his brothers still runs a shooting gallery in New England.

Garand's formal education consisted solely of a short period spent in a Catholic grade school in St. Remi. When he was about 12 his mother died and his father moved the brood to the United States, settling finally in Jewett City, Conn. When he was 14 he went to work in a cotton mill as a bobbin boy and apprentice, and a couple of years later was put in the shop where he got experience in pipe-fitting, tool-making, benchwork, gear-cutting, and other useful skills. He started an International Correspondence School course in steam engineering but didn't complete it. When he was 21 he was fired for making a model water-wheel one Sunday afternoon out of the company's brass scrap, so he went to work in a Providence welding shop. This was not very exciting, so he made up for it by buying a motorcycle which he rebuilt for speed and rode in local motorcycle races. On several occasions he got better than 90 m.p.h. out of his creation, and in 1910, his best year, he won 19 out of the 21 races he entered. This sport led to several bad spills, however, and after a particularly bloody wreck, he gave up motorcycling for ice skating and target shooting. At about this time he became a citizen of the United States.

In 1916 he went to work as a toolmaker and designer in New York, spending his evenings at shooting galleries on Sixth Avenue. His marksmanship was so spectacular — he used to fire a rifle from the hip — that he was allowed to shoot free because of the business he attracted. About this time he joined the 1st Field Artillery of the National Guard in order to occupy his spare time, and while he was training with his company he heard that the government was looking for an improved machine gun. This set him to work; his design, though it was not accepted, was instrumental in interesting the Ordnance Department in his talents, and it was not long after that, in 1917, that he was employed by the National Bureau of Standards in Washington on gun tests. Two years later he was transferred to the Springfield Armory where he has unostentatiously turned out gun designs ever since.

When Garand married in 1930, the first thing his wife did was to persuade him to stop using the living room for a skating rink. For several years before his marriage he had partitioned off a 12x12-ft. area in the front room of the house he owned in Springfield, knocked a hole in the chimney to create a draft, and each winter flooded the floor with water. With the windows open this gave him a nice smooth ice surface on which to practice fancy skating. On week-ends he would travel to New York and take lessons at Iceland so that he could do the spread eagle and other figures. At his bride's behest he built a rink in his backyard, where each winter he still tries to master the intricate figures of Sonya Henie. He says he is never likely to be too good, though; he's not limber enough.

The Garands have two children; a boy of eleven whom his father is teaching to be a marksman, and a daughter a year older who is on her way to being a figure skater under papa's teaching. His other interests outside of his work include bridge and flower gardening with his wife, and checkers with his cronies on the benches of Winchester Square during lunch hour.

At the arsenal Garand is known to all as "John", and is a source of amazement to the young men with college degrees who work under him. Despite his lack of any formal mathematical training, he attacks and solves problems in his direct and original method with such dispatch that some of his young men are occasionally tempted to break their slide rules over their knees, and throw away their calculus texts. He is utterly absorbed in his work, almost to the point of being absent-minded about everything else, and his reading is for the most part technical. He regularly reads *Engineering*, *The American Machinist*, *Machinery*, and *Metal Progress*.

Garand is not unduly impressed with his achievements as a designer of guns, and his acclaim has not changed his manner of living or his fortunes. He could undoubtedly earn a lot more money working for a private arms company, and he could have made a fortune from the royalties on the private and foreign sales of his guns, due him under the terms of his contract with Uncle Sam. These royalties he voluntarily assigned to the government as a patriotic gift, and he has made no effort to capitalize on his fame in any way. At one time a Massachusetts congressman introduced a bill in Congress, appropriating $100,000 to Garand in recognition of his services. This bill was tabled and forgotten — forgotten not only by the Congress but also by Garand who, when reminded of it recently, was mildly surprised. He didn't seem to miss it!

E. C. McD.

NE Steels in Oil Well Drilling Equipment

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Drilling equipment is subject to severe service and is designed with low factors of safety, nevertheless NE 8700 series steels have been quite satisfactorily substituted for S.A.E. 3100 and 4100 steels formerly used for tool joints and drill collars, and for S.A.E. 4800 steels formerly used for rock bits. No acceptable substitute has, however, been found to give the corrosion resistance of 1.5% nickel steels, required for sucker rods immersed in oxygen-free fluid carrying considerable soluble sulphide.

EXPERIENCE of the oil industry in the use of National Emergency steels for oil well drilling and producing equipment is considerably less extensive than that of some other industries. There are several reasons for this condition.

Early in the national emergency, the Office of the Petroleum Coordinator issued an order limiting the spacing of oil wells to one well for each 40 acres and one gas well to each 640 acres. These spacings are wider than those commonly used and, as intended, drilling of wells was curtailed. In 1940 there were 30,040 oil and gas wells drilled in the United States. This figure increased to 32,140 in 1941. The spacing order caused the number of wells drilled in 1942 to decrease to 21,454 and in 1943 there was a further decrease to 17,941. This represents a curtailment to only 56% of the rate for 1941. With so little drilling going on, there was a corresponding slump in demand for the equipment.

Another reason for the limited experience of the oil industry with NE steels is that until late in 1942 the priority allotted to drilling and production equipment was not high enough to allow more than very limited manufacture. Since that time considerable emphasis has been placed on the necessity for increasing the flow of crude petroleum and for intensified efforts to locate new oil fields. Consequently, more steel has been allotted to the oil industry since the middle of 1943. Much of this has been NE steel.

The service conditions imposed on oil well drilling and producing equipment are severe. The machinery used for drilling a deep well must be heavy to withstand the high loads but, at the same time, it must be portable and capable of rapid assembly on foundations that are hardly more than temporary. Therefore, both weight and size are important design factors. Vibration is excessive and it is impossible to provide adequate protection against the weather, particularly blowing sand. Power generated at the surface must be converted to work far below the surface by the drill pipe, which functions as a drive shaft often more than 10,000 ft. long. Similarly severe conditions are common in the operation of producing equipment. Consequently, safety factors are unusually low and alloy steels are essential.

Prior to the advent of the NE steels, there were approximately 36 different alloy steels of 20 different base compositions used for the principal items of oil field equipment. Substitute NE steels selected from the first list, including the S.A.E. 4000 series, then reduced the number of alloy steels required to 26 specifications of 15

different types or base compositions. An industry subcommittee on oil tools and drilling equipment, charged with the selection of substitute steels from later NE lists, has effected still further simplification.

During the last six months of 1942 the experience of one manufacturer in the fabrication of 7500 tool joints indicated that NE8442 (low side in carbon) was a very satisfactory substitute for the S.A.E.3140 previously used. A second manufacturer had a similarly encouraging experience in making more than 5000 tool joints from NE8739 and 8744 (later replaced by NE8637 and 8642, 5 points lower in molybdenum) as substitutes for A3140 and A4140. A majority preference for the lower Cr-Ni-Mo series over the higher Mn-Mo series steels was expressed for this application, but it could be concluded at least tentatively that either type of steel afforded a reasonably adequate substitute for the Ni-Cr or the Cr-Mo steels for tool joints. Typical physical properties for several early heats of full hardening NE steels are compared in Table I with those of S.A.E. steels used previously. Most of the physical property data relate to tool joints, which are generally heat treated to Brinell hardness within the range of 285 to 335.

When it became necessary, as it did in 1943, to use a substitute for the 8600 and 8700 series steels for tool joints, the NE9400 series steels, used by the industry under protest, did not prove to be as satisfactory. Difficulty was encountered in obtaining the required physical properties and in machining tool joints made of NE9440 and 9442. It was also found that these steels were likely to respond erratically when drawn at temperatures above 1000° F. In view of these several fabricating difficulties the use of the 9400 series steels was discontinued as soon as permitted and, at the present time, nearly all tool joints are made from either the NE8600 series or the NE8700 series steels in the carbon range of 0.40% to 0.50%. The tendency is definitely toward a final preference for the 8700 series. Recent experience with these steels indicates that the physical properties listed in Table II are representative. It seems quite probable, however, that the new NE9800 or 9900 series steels may be selected ultimately unless the pre-war steels should soon become available again to the oil industry.

Table I — Comparison of Full Hardening NE Steels and Pre-War Alloy Steels As Used For Tool Joints, Rock Bit Parts, Reamer Bodies, and Subs

Steel	Heats	Tensile Strength	Yield Strength	Elongation in 2 in.	Reduction of Area	Brinell Hardness	Izod Impact
NE8339 *(a)*	1	144,000	132,000	20.0	56.8	311	50
NE8739 *(b)*	1	138,500	113,500	18.0	58.3	311	60
NE8744 *(c)*	3	137,500-148,500	100,000-126,800	14.0-17.5	54.8-57.5	301-321	19-52
A3140	1	156,000	141,000	17.0	54.1	321	39
A4140	1	160,000	150,000	18.0	54.9	321	44
A4142	3	144,600-156,700	126,600-140,000	14.5-18.8	55.0-60.5	321-332	31-62
NS4245 *(d)*	4	154,200-160,000	140,400-144,800	17.0-17.5	53.0-55.0	321-332	42-49

Footnotes:
(a) 8442, low side in carbon and molybdenum.
(b) 8637, low side in manganese and molybdenum.
(c) 8642, low side in manganese and molybdenum.
(d) Manufacturer's designation for A3145 containing 0.15 to 0.20% molybdenum.

Table II — Comparison of NE8600, 8700, and 9400 Series Steels As Used For Tool Joints *(a)*

Steel	Tensile Strength	Yield Strength	Elongation in 2 In.	Reduction of Area	Brinell Hardness	Izod Impact
NE8640	153,000	135,000	16.0	53.6	331	44.0
NE8640	140,000	115,000	18.0	60.3	311	53.0
NE8640	160,000	145,000	18.0	58.3	331	49.0
NE8640	148,000	130,000	20.0	62.8	321	56.0
NE8744 *(c)*	149,800	133,300	19.5	59.1	311	61.0 *(b)*
NE8744 *(c)*	144,400	121,400	19.0	58.5	304	
NE9442	130,000	110,000	23.5	62.8	277	69.0
NE9442	131,500	110,000	18.5	61.8	302	61.0
NE9445 *(d)*	140,100	116,800	19.0	49.0	311	

(a) Oil quenched and drawn to Brinell range of approximately 280 to 330.
(b) V-notch Charpy test piece.
(c) Drawn at 1125° F.
(d) Drawn at 950° F.

In the early use of the substitute steels, NE8739 and NE8742 (now respectively NE8637 and 8642, high side in molybdenum) were substituted successfully for S.A.E. 3140, A3140, A4140, NS4245 (A3145 plus 0.17% Mo), A3141, and A4142 for drill collars, kellys, and subs. It was necessary for a time to use the 9400 series steels for these parts also; NE9444 and NE9450 were

Table III — Comparison of Normalized Longitudinal and Transverse Physical Properties of Drill Collars Forged From NE8645 and NE9445

Steel	Draw Temperature	Direction of Test	Tensile Strength	Yield Strength	Elongation in 2 In.	Reduction of Area
		Tests on Steel in Normalized Condition				
NE8645	1000° F.	Longitudinal	131,800	93,200	17.0	44.7
		Transverse	130,900	92,100	11.0	21.0
NE9445	1000	Longitudinal	117,300	71,500	17.0	32.3
		Transverse	116,700	66,400	12.0	20.9
NE8645	1200° F.	Longitudinal	104,800	72,400	22.5	55.5
		Transverse	101,600	69,700	16.0	27.3
NE9445	1200	Longitudinal	110,200	65,700	20.5	41.2
		Transverse	110,800	60,700	15.5	20.3
		Oil Quenched From 1550° F.				
NE9445	950° F.	Longitudinal	140,100	116,800	19.0	49.0
		Transverse	139,400	115,700	13.0	32.1
NE8645	1125° F.	Longitudinal	144,400	121,400	19.0	58.5
		Transverse	143,400	119,300	15.5	35.6
NE8645 (tool joints)	1125° F.	Longitudinal	149,800	133,300	19.5	59.1
		Transverse	146,600	124,300	15.5	38.4

so used. The same objections mentioned with relation to tool joints were registered by all manufacturers of such equipment. At the present time the steels being used are: NE8744, NE8749, and A4142. This preference is understandable readily from the results in Table III which gives a comparison of the longitudinal and transverse properties of forged drill collars and tool joints.

During the latter half of 1942 one manufacturer produced about 3000 rock bit parts from NE8420. [specially produced steel, not on any official list] and this substitution for S.A.E.4815 has given satisfactory results in 85% of the cases. A comparison of the physical properties of the cores of several NE and pre-war alloy carburizing steels is given by the data in Table IV. From these data, reported by equipment makers, it appears that the NE steels with higher nickel, chromium and molybdenum contents provide somewhat greater impact strength and, therefore, for severe service are preferable as substitutes to the manganese-molybdenum steels.

Experience during 1943 confirmed the early suspicion that none of the NE carburizing steels would prove to be an entirely satisfactory alternate for carburized parts subjected to heavy duty, such as cutters and reamers on drilling bits. This evidence became so conclusive that a petition to use pre-war A4815 for these parts was allowed by the War Production Board in September 1943. For parts subjected to less severe service, such as slips, taps, die collars and tongs, NE8720 is proving successful.

Corrosion Fatigue — Engineers, both of the oil industry and of the equipment manufacturers,

Table IV — Comparison of Core Properties of Carburized NE and Pre-War Alloy Steels As Used for Parts of Rock Bits for Oil Well Drilling

Steel	Tensile Strength	Yield Strength	Elongation	Reduction of Area	Brinell Hardness	Izod Impact	McMullan Case Strength
NE8024	156,000	131,500	14.5	40.6	302	24	
NE8124 *(a)*	159,000	127,500	15.0	49.5	293	25	307,500 psi.
NE8422 *(b)*	150,500	141,000	18.0	54.5	321	45	249,000 psi.
NE8620	121,500	90,000	23.0	59.6	229	69	
NE8630	144,000	127,500	20.0	63.2	293	66	241,000 psi.
NE8720	121,500	102,000	22.0	63.5	262	77	
NE8817 *(c)*	154,500	130,000	16.5	60.1	311	65	
NE8922 *(d)*	158,000	125,000	18.0	54.1	321	..	365,000 psi.
A3115	138,500	117,500	19.0	49.0	302	55	
A4815	151,000	120,000	19.0	61.0	321	44	

(a) 1.30-1.60% Mn, 0.25-0.35% Mo
(b) 1.30-1.60% Mn, 0.30-0.40% Mo
(c) 0.70-0.95% Mn, 0.30-0.40% Mo, 0.40-0.60% each Cr and Ni
(d) 1.00-1.30% Mn, 0.30-0.40% Mo, 0.40-0.60% each Cr and Ni

Table V — Experimental Compositions of Special Alloy Steels for Sucker Rods

Constituent	Nickel-Copper Steel	Nickel-Chromium Steel	Nickel-Molybdenum Steel
Carbon	0.20-0.25	0.30-0.40	0.25-0.30
Manganese	0.75-1.00	0.50-0.70	0.75-1.00
Silicon	0.15-0.30	0.15-0.25	0.15-0.30
Nickel	1.20-1.50	0.70-0.90	1.10-1.40
Chromium	—	0.30-0.50	—
Molybdenum	—	—	0.08-0.15
Copper	0.50-0.80	—	—

were nearly unanimous in thinking that sucker rods for heavy pumping loads under sulphide corrosion conditions could not be made of NE steel without incurring a considerable reduction in durability. Years of experimentation and experience have proven conclusively that there is no entirely suitable substitute for the nickel content of S.A.E.4615 and higher nickel steels that were used for this service. In this case it is not a problem of obtaining certain ordinary physical properties. Rather, it is a problem of equaling the resistance to sulphide corrosion fatigue in the absence of oxygen which is imparted by a nickel content of 1.5% or more. No other alloy or combination of alloys has yet been found which equals nickel in such service.

It was not until 1943 that any alloy steel was allocated to this use. The industry protested successfully against the use of any NE steel for this purpose. As a result of discussions between representatives of the industry, War Production Board, and Petroleum Administration for War, a test program was inaugurated to determine if a reasonably satisfactory alternate could be used to effect some saving in alloys. Three special compositions were selected as given in Table V. The nickel-chromium steel had been used for many years previously where corrosion conditions were only of moderate severity, and it was known to be inferior under severe conditions. The results of these tests indicated that the nickel-molybdenum steels and the nickel-copper steels tested — the latter utilizing monel metal scrap — were nearly equivalent and that either was superior to the nickel-chromium steel, but even so, both were inferior to the modified S.A.E.4620 (with about 0.30% Cr) which was the pre-war standard composition. At the present time, the use of this steel is permitted and the compositions of sucker rod steels have reverted to their pre-war status.

The prospects for the continued use of NE steels in the post-war future for the manufacture of oil field equipment do not appear to be particularly promising. Unless the new series just announced meet with a greater acceptance, the NE8700 series probably will be the only survivor and even their use will most certainly depend upon suitable price adjustment.

The information in this account of experience with the use of NE steels was furnished by members of the War Production Board Technical Advisory Committee on Oil Tools and Drilling Equipment.

Bits and Pieces

Metallurgicus's

Own Page

Identification of Brinell Balls

IN "BITS AND PIECES" in the May issue, a chemical spot test was described for separating tungsten carbide balls and steel balls for Brinell testing machines. In response to requests for alternative tests, Harry P. Coats, chief chemist and metallurgist for Firestone Steel Products, and Louis A. Carapella, industrial fellow at Mellon Institute, both suggest the use of a magnet which attracts the hardened steel balls much more strongly. The use of a cathode-ray oscilloscope or "Cyclograph" described in *Metal Progress* for September 1942, page 394, is suggested by R. W. S. Freeman of Ontario Research Foundation and David Gross of Allen B. DuMont Laboratories. Max Herzog, Chief Chemist for the St. Louis-San Francisco Railway Co., calls attention to the large difference in specific gravity, the 10-mm. steel Brinell balls weighing about 4.10 g. while tungsten carbide balls weigh from 6.6 to 7.8 g.

"It is not quite so simple to distinguish between steel balls of the quench hardened type and the Hultgren cold worked type, although with a little care it can be done positively," continues Mr. Herzog. "The Hultgren balls are usually etched and the quench hardened balls brightly polished, in which case identification is easy. The Hultgren balls are about two points higher in Rockwell hardness than ordinary Brinell balls, the values for the two types of balls tested in this laboratory being C-64 and C-62 respectively. (A single Rockwell indentation would not affect the value of the ball for making Brinell impressions.) Another method for separation would be to make a Brinell impression with each on a piece of steel having a hardness of 600 Brinell or above, the ball giving the higher hardness reading being the Hultgren ball. Quench hardened and cold worked balls can also be distinguished by the magnetic tester described by C. S. Williams of Westinghouse in the January 1942 issue of *Metal Progress*, in which differences in heat treatment between two small steel parts are shown up in the pattern traced by an oscillograph when the parts are inserted into two small coils connected in opposition and placed in an alternating magnetic field. Relatively few laboratories, however, are equipped to make a test of this kind."

Spotting Cobalt High Speed

MY EXPERIENCES in spotting cobalt high speed with a drop of HCl, as suggested by George Roberts in *Metal Progress* for May, have shown that many times it is difficult to detect the bluish color, especially when the pieces are rusty and dirty. Furthermore, if the pieces are either heavy or numerous, the task of separation becomes quite laborious. A modification of this method which has been used with excellent results consists of dipping the lower half of a strip of filter paper into the concentrated acid and then laying it on the piece to be tested. The presence of cobalt causes the paper to turn a bluish color within 30 to 60 sec. (M. ROBERT GROSS, Metallurgist, U. S. Navy Metals Laboratory)

A Film Dryer

FREQUENTLY it is desirable to obtain metallographic prints as quickly as possible, whereupon the "bottle-neck" has been the time required for drying the film. Efforts to speed the drying often have resulted in ruining the film. This eventually led to the dryer illustrated, whose construction is so simple and results so gratifying that others certainly would like to build one.

The vertical pipe is a 2¼-ft. section of 10-in.

galvanized sheet iron pipe. The heating element consists of 40 ft. of 20 g. Chromel "A" wire, coiled by winding on a ¼-in. rod, and threaded through transite board (see Fig. 1c). With 110-volt current, the drying time for film is 18 min.

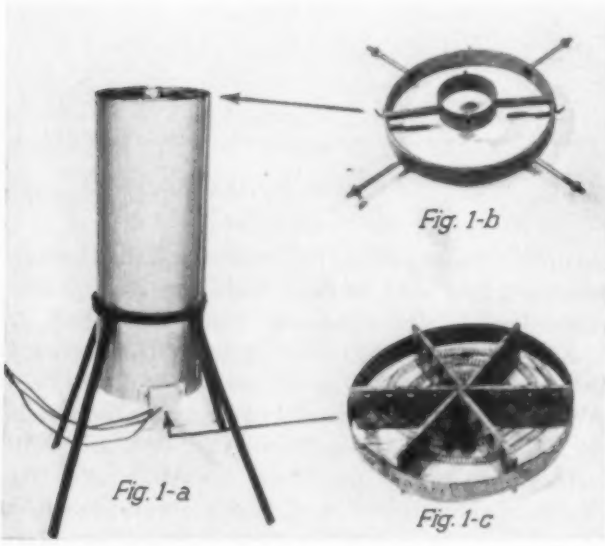


Fig. 1a Represents the Complete Dryer; Fig. 1b the Film Rack and Fig. 1c the Heating Element

By tapping the center of the element and connecting the two halves in parallel, the drying time is reduced to about 9 min. The faster drying rate causes some curling but otherwise is not harmful to the film.

To prevent the formation of water spots it is necessary to treat the film with one of the surface tension reducing agents such as Fisher Scientific Co.'s "Aerosol". After washing, and before hanging in the dryer, the films are held in the Aerosol solution for about 30 sec.

The drying rack shown in the illustration will hold six 5 by 7-in. films, punched on the edge with a paper punch, and hung on the hooks shown in Fig. 1b. (Earl J. Eckel, Associate in Metallurgical Engineering, University of Illinois)

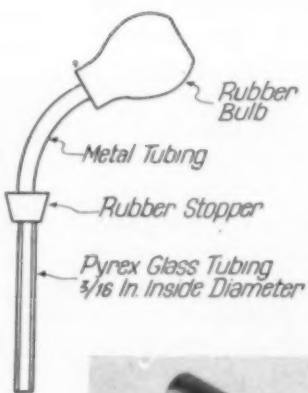
Sampling Molten Metals

Some time ago George Motok of Republic Steel Corp. proposed a sampling procedure which very simply prepared a pencil of metal for use in the arc spectrograph. It has since proven to be a very convenient method for obtaining a short smooth steel rod or even a seamless tube for other tests or applications.

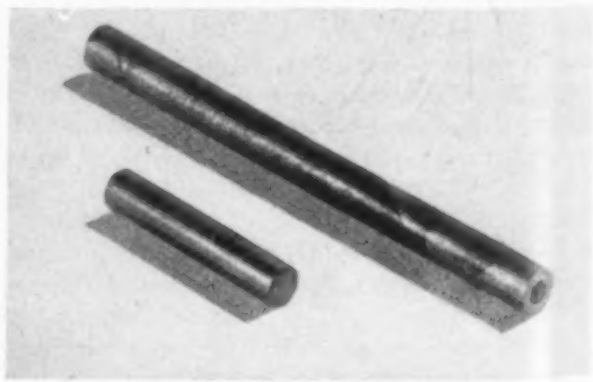
Motok's equipment is shown in the adjoining sketch. Fundamentally the procedure consists of compressing the rubber bulb, dipping the tip of the warmed pyrex tube into a killed molten steel bath, and sucking metal up into the pyrex tube where it solidifies. The glass tube, which is inexpensive, is then broken away and a pencil of metal is available for analysis.

Such a pin, if properly quenched, may be used for a rapid determination of carbon content in plain or low alloy steels. To prepare the sample, the glass tube full of hot metal is grasped with pliers or tongs near the top of the metallic column and quenched immediately into an iced brine bath. If the steel has been properly deoxidized the surface will be so smooth that Rockwell hardness readings can be taken directly on it. Maximum hardness will be where the glass first breaks away from the specimen in the quench.

This sampling technique may be varied slightly to produce a short length of seamless steel tubing with outside diameter corresponding to the inside diameter of the pyrex tube used. If the pyrex tube is removed from the bath before the top of the metallic column is frozen over, the molten metal will drain out leaving a steel shell. Three forces are at work — *(a)* a vacuum pulling the column of molten metal up, *(b)* gravity pulling it down, and *(c)* surface tension tending to make the metal flow smoothly around the periphery. Freezing starts on the cool wall of the pyrex tube and proceeds inward as the heat is transferred away. Reproducibility in tube wall thickness depends upon perfect timing in combining the factors of vacuum, gravity, surface tension, heat transfer, and quench.

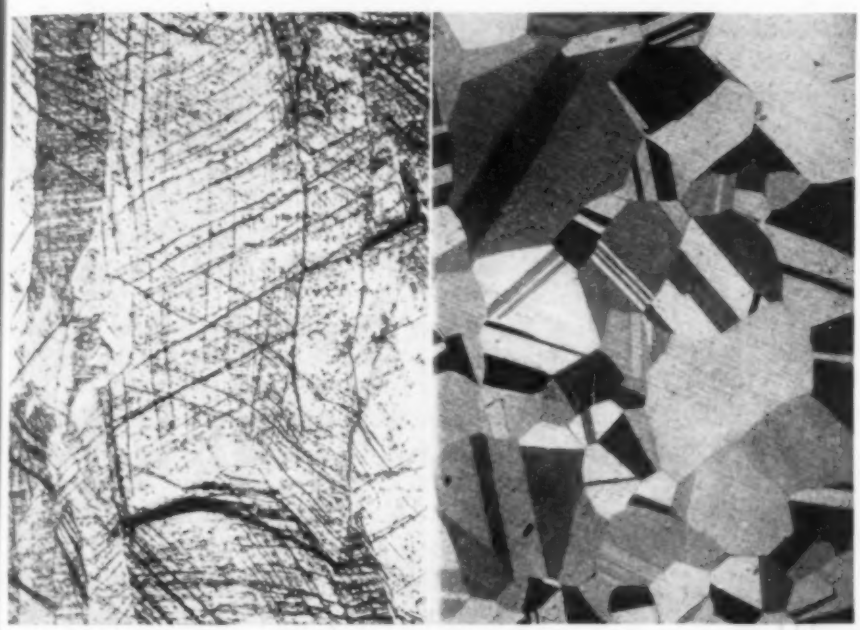


This method may be applied also to molten metals other than steel. Pencil of steel and tube are photographed herewith. (N. C. Fick, Battelle Memorial Institute)



Unusual Type of Precipitation

THE MORE one works with alloys, the more often new structures come to light. Readers of "Bits and Pieces" may also have some strange ones of their own, or a logical explanation for the one at the left. It is at 150 diameters, etched with ferric chloride. Analysis is 72% copper, 18% manganese, 10% nickel. It was a cast ⅝-in. rod, solution treated at 1200° F., water quenched, swaged cold from ⅝ to ⅜ in., heated to 750° F. for 14 hr. and water quenched. It shows an unusual type of precipitation structure. The right hand figure is the same specimen after reheating to 1650° F. and water quenching. (Magnified 75 diameters; etched with ammonia and peroxide solution.) There is nothing unusual about this one; the metal obviously has been thoroughly recrystallized. (CHARLES Y. CLAYTON, Professor of Metallurgy, Missouri School of Mines)



Wrought Iron Pipe Replaces Copper Bus Bars

A LOT of deserved publicity has been given the use of silver, borrowed from the United States Treasury, to replace scarce copper for carrying the heavy currents at low voltage into the cell rooms in the new magnesium and aluminum reduction plants. Equally unique, I think, is the use of standard 4-in. wrought iron pipe in place of the more conventional copper or aluminum busses for high voltages at large power stations, notably at Bonneville Dam on the Columbia River. This pipe is amply good to carry the 115-kv. and 230-kv. current generated here, ready for transmission. The current-carrying capacity may be further increased, if necessary, by slotting the pipe along its length to break the ferrous loop, and by coating the pipe with a dull black paint to increase the radiation of heat. In addition to its low cost, wrought iron pipe in this service has the following advantages:

1. Wrought iron has a high modulus of elasticity, permitting long spans, particularly with ice and wind loading, thus saving on insulators, fittings and supports.

2. It has good corrosion resisting properties. Paint gives it additional protection and is easy to apply.

3. Welding is an easy, quick and economical way of joining the pipe into whatever bus arrangement is desired. All clamp type fittings are eliminated, since welding produces joints that have high electrical efficiency as well as permanence. Welded busses also are found to reduce corona formation.

4. Wrought iron expands less than copper or aluminum, necessitating fewer expansion joints in long runs. (J. A. GERBER, Assistant Engineer, Bonneville Power Administration)

An Improved Method of Flow Line Etching for Nitralloy

METAL FLOW in a forging can usually be shown by macro-etching a longitudinal section. Due to considerable difficulty in obtaining such flow line patterns in nitralloy steel, and after considerable work with various reagents, a method was evolved which is comparatively simple, and gives exceptionally good results. This technique has been tried on a number of different steels, and it works excellently in every case.

Preparation of Sample — Cut the sample as nearly parallel to the flow lines as is possible, grind out the saw marks, and smooth on a belt sander or its equivalent. (A surface grinder is not recommended as a final smoothing tool as it leaves patterned areas of worked surfaces which

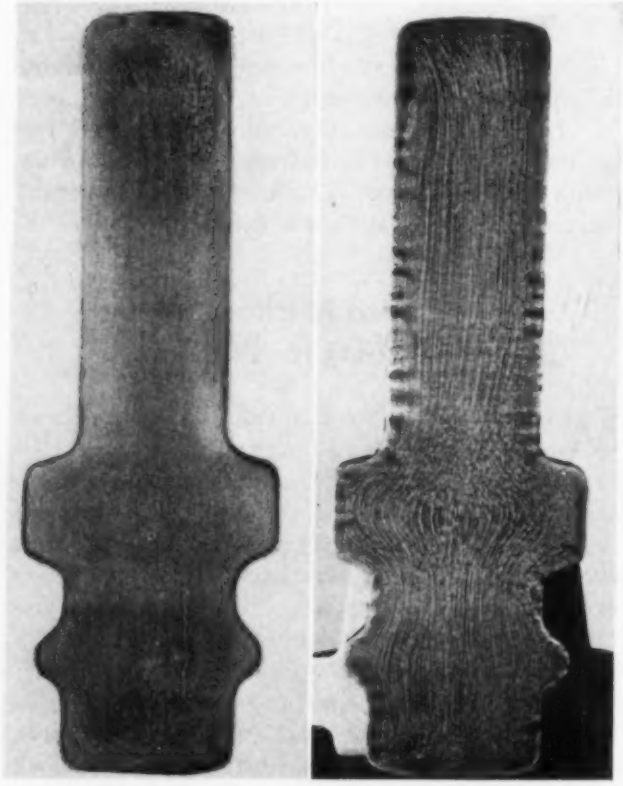
etch faster than other areas.) The finished surface should be smoothly ground or polished.

Reaction Time and Temperature — After the specimen has been cleaned, it is immersed in a 15% aqueous ammonium persulphate solution at 160° F. The face of the specimen should not touch the container. Etching with the face up is recommended. In most cases 10 min. at 160° F. is sufficient. After the etching has been completed wash the sample in water and dry it in air.

Treatment After Etch — If these operations have been carried out properly the etched surface should be uniformly black. The surface is now gently rubbed with a cloth. As a final step the surface is polished with a fine grade of emery paper bringing out the contrast between the flow lines. Polish to maximum contrast.

A pair of pictures are submitted to illustrate a forging, etched with the conventional etching acid technique and the same forging etched by the new method. These samples are halves of the same forging; both were prepared in the same way and no special preference has been given to the sample etched with ammonium persulphate.

If this technique is followed it will give excellent results. It is especially recommended for nitralloy forgings where considerable difficulty has been encountered in bringing out these lines. However, the method will perform not only on nitralloy but on all other S.A.E. steels as well. This method, besides bringing out the flow lines, will also show up the areas of decarburization which in many cases are equally interesting to the metallurgist. (Martin Burg and George Weiss, Chemical Engineers, Chrysler Corp.)



Gear Blank of Nitralloy G, Split Longitudinally. One half deep etched in 1-1 HCl, and the other half with improved etchant as recommended

Simple Die Converts Press Into an Upsetter

A BOTTLENECK in our forge shop was broken by using a suggestion made by Joe Miller, one of our veteran blacksmiths. His idea was judged worthy of a $500 award. The job consisted of making a considerable number of short husky shafts for electric generators for the U. S. Navy, about 8 in. diameter and 4 ft. long, flanged on one end. Normally they would be forged down in a steam hammer from a billet somewhat larger than the flange. Production schedule required 20 hammer operators on each shift. Neither manpower nor machinery was available.

Miller's idea was to upset the end of a round into a flange, but we had no upsetter capable of the job — if, indeed, there was one large enough in existence. We therefore utilized a 1000-ton hydraulic press. On the anvil we built up a die of six thick steel rings bolted together to form a six-ton steel cylinder about the size of an oil drum. A hole slightly larger than the diameter of the shaft runs through the center of the rings. A stop at the bottom positions the shaft. The top ring was bored with a larger hole, the diameter and thickness of the required flange.

Since only one end is heated before the bar is placed in the die, only that section is upset. Naturally some heat is conducted down the entire length, but not enough to make the metal plastic. This fact, in conjunction with an oversized hole through the center of the die, prevents sticking. The upper platen of the press, on descending, upsets the flange in a single stroke. After the pressure is relieved, a wedge is driven into the bottom of the die and the forging pops up where it can be lifted out with tongs.

Because there are no hammer marks that must be machined out, this method requires a steel bar weighing 130 lb. less than the billet needed to forge down a shaft under the hammer. Hence this method has four big advantages over forged shafts: *(a)* it greatly increased production; *(b)* less metal is used; *(c)* it requires less machining; and *(d)* it utilized one machine where 20 otherwise would have been required. (W. C. Rowland, Superintendent, Factory Service Division, Westinghouse Electric & Mfg. Co.)

The Nitriding Process;

Factors Influencing Ammonia Consumption

By C. V. Snell
Technical Service Dept.
Armour Ammonia Works
Chicago

Normal operation at 970°F. consumes 20 to 30 cu. ft. of ammonia gas per hr. for every 100 sq. ft. of surface being nitrided. Operating temperature, analysis of steel, and surface smoothness, all influence consumption, and the author suggests a two-stage process to reduce the gas consumption and eliminate the "white layer". A new method for measuring case depth is also described.

DEMAND for parts having increased wear resistance, hardness at high temperature, resistance to certain types of corrosion, and hardenability with a minimum of distortion has resulted in a rapid broadening of the applications of nitriding during the past few years. However, published information concerning factors influencing the operation has been lacking. Accordingly, the following has been compiled from our work with numerous installations, with the thought that any addition to the information on nitriding will be of value, both in its application to present problems and to post war planning.

Consumption — Comprehensive information on the rate of ammonia consumption is lacking. D. Landau, in his booklet on "Nitriding Furnaces" published by the Nitralloy Corp. in 1943, quoted consumption per hour or per pound of steel treated in definite installations, but observed that a figure on average consumption per unit area nitrided had been computed. This figure was used as a start by the present writer.

All other factors remaining constant, such as temperature, length of cycle, and effect of the retort, the amount of dissociated ammonia in the exhaust gases (and therefore the ammonia consumption) is directly proportional to the surface area of the parts being nitrided. The surfaces protected by stop-off material, such as tin plating, nickel plating or "Sel-Nite", do not enter into the reaction. Information from a number of installations using most of the popular makes of furnaces showed that, in most instances, an average of 20 to 30 cu.ft. (0.9 to 1.3 lb.) of ammonia gas per hr. is consumed for every 100 sq.ft. of surface being nitrided at 965 to 975° F. The range is wide because of the numerous minor variables. However, it is based on maintaining an average dissociation of 30%, and holds true only where the retort and fixtures are in good condition and where there is adequate circulation of ammonia.

Effect of Increasing Dissociation — Ammonia consumption can be decreased by as much as 60% by boosting the dissociated ammonia in the exhaust to 60%. In the past, it has generally been recommended that dissociation be held to about 30%, but recent experiences in a number of large commercial nitriding installations have proven that satisfactory results can be obtained even if dissociation goes as high as 60 to 70%. In a study of the nitriding process presented before the ASM convention in Chicago, 1943, Carl F. Floe concluded that dissociation as high as 65% did not sacrifice any case depth. It was further shown that after first nitriding at a dissociation of around 30% for a short period, the dissociation can be allowed to increase to a maximum of 85% and still obtain a satisfactory case.

On larger installations, where adequate circulation may be difficult and result in stagnant gas pockets which might be dissociated more than average, operating at the maximum dissociation of 85% would not be recommended. Probably 60 to 70% dissociation should be taken as the maximum that should be allowed in most furnaces having a closely packed load. It is usually considered good practice to start the heat with a lower dissociation of about 30% for 10 hr., and then increase to 60 or 70% for the remainder of the time.

The "White Layer"

High dissociation has an advantage other than ammonia savings. It was shown in Dr. Floe's paper that the "white layer" can be almost entirely eliminated by following this practice. Since the white layer is brittle and tends to spall, it is usually undesirable and is removed by a lapping operation. This lapping operation can be shortened and in some cases eliminated, a matter of major importance on certain parts such as gears.

In furnaces containing loads having comparatively small effective surface areas, difficulty may be encountered in maintaining more than 30 to 40% dissociated ammonia in the exhaust gases. In such cases, after the first 5 to 10 hr. at heat, the ammonia flow into the retort should be decreased until the percentage dissociation of the exhaust gases approaches 60 to 70%. Since dissociation is directly proportional to the area being nitrided, obviously if the nitriding area is small only a comparatively small quantity of ammonia will be dissociated, and thus it may not be possible to get the exhaust up to 60% and still pass sufficient ammonia into the retort for adequate circulation and to give a positive pressure. Where this is the case, introduce controlled amounts of dissociated ammonia with the fresh gas going into the heat treating muffle, either by recycling the exhaust gases or by dissociating ammonia in separate equipment. Ammonia dissociators of 25 cu.ft. per hr. capacity and larger are available from several furnace manufacturers. They produce a mixture of 75% hydrogen and 25% nitrogen, with only a trace of ammonia.

In figuring the savings it should be noted that a 50% dissociation does not mean, as might appear, that 50% of the ammonia entering the retort or muffle is being dissociated. Ammonia gas doubles in volume on dissociation according to the reaction $2NH_3 \rightarrow N_2 + 3H_2$. In other words, two volumes of ammonia yield four volumes of the elementary gases. Actually, a "dissociation of 50%" means 50% by volume of the exhaust gases is dissociated ammonia (molecular hydrogen and molecular nitrogen) and 50% is ammonia gas. In terms of the entering ammonia, it means that ⅓ or 33% of the ammonia being introduced into the furnace is dissociated while ⅔ or 67% is exhausted as unchanged ammonia gas.

Austenitic Steels — Allowing the dissociation to increase into the range of 60 to 70% is suggested only when treating Nitralloy steels. For nitriding steels higher in alloy content, experience in several installations has indicated that lower dissociation must be maintained, the actual figure depending to some extent on the percentage of elements that readily form nitrides, such as chromium and molybdenum, in the steel. For example, the common stainless steel containing 18% chromium and 8% nickel requires a dissociation under 30% for maximum case depth. The figure for average ammonia consumption already quoted does not necessarily hold true for such high alloy steels. No accurate averages are available, but there are indications that they consume as high as 75 to 100 cu.ft. of ammonia gas per hr. for every 100 sq.ft. of surface being nitrided, the actual consumption depending on the temperature and alloy content.

Maximum Corrosion Resistance — For parts where maximum corrosion resistance is desired, the lower dissociation rate is still recommended. Nitriding with 30% dissociation results in a comparatively heavy white layer, high in nitrogen (approximately 12%). In comparison with this the case at the point of maximum hardness — 0.002 to 0.004 in. from the surface — contains around 3% nitrogen. The high nitrogen surface, or white layer, is thought to be most effective in corrosion resistance; hence if parts should have maximum corrosion resistance no appreciable amount of this layer should be removed. Usually such a part is finish-ground before, and polished after nitriding. A highly polished surface *prior* to nitriding may result in slowing up the reaction.

Corrosion resistance is apparently dependent on the fact that the metallic nitrides, being fairly stable, do not readily convert to oxides or other salts. On this basis the corrosion resistance will be in direct proportion to the nitrogen content of the exposed surface. As the dissociation maintained during the nitriding cycle is allowed to increase, the thickness of the white layer tends to decrease — hence the lower figure of 30% recommended. Also, since the white layer tends to build up with longer cycles and lower temperatures, a cycle as long as conditions will allow (preferably up to 60 hr. at 950 to 965° F.) is preferable for maximum corrosion resistance.

Effect of Poor Circulation — The effect of too high a dissociation — either locally, as in a pocket caused by poor circulation, or over the entire load — should be considered. Experience has shown that if the dissociation is allowed to go over 85%, the maximum case may not be obtained. Also, there is a possibility of denitriding, which has been encountered experimentally in the dissociation range above 85%. Denitriding usually results in the formation of minute surface cracks which ruin the part.

Effect of Temperature — Ammonia consumption is dependent upon the nitriding temperature, other factors being equal. The quoted rate of 20 to 30 cu.ft. is based on a nitriding at 965 to 975° F., as in the majority of commercial installations. At higher temperatures, above 990° F., dissociation — therefore consumption — increases rapidly. At lower temperatures (around 940 to 950° F., which is about the lowest employed commercially) the ammonia consumption is lower,

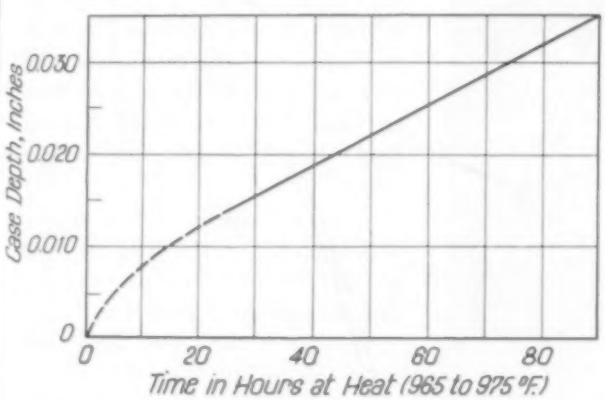


Fig. 1 — Curve Averaging a Number of Observations on Case Depth for Definite Time at Heat (965 to 975° F.) and for Nitralloy Steels (Nitralloy-N Excepted)

apparently by about 20%. However, experience has shown that a case 0.002 to 0.005 in. deeper is obtained by nitriding 50 hr. at the usual 965 to 975° F. than when nitriding under the same conditions except at a temperature of 940 to 950° F. Hardness required also is affected; the lower temperatures of 940 to 950° F. give a harder case. For example, 93 on the Rockwell superficial 15N scale is about the average hardness obtained at 965 to 975° F. in commercial nitriding installations, while nitriding under the same conditions, except at a temperature of 940 to 950° F. usually results in at least 95 on the 15N scale.

The theory behind this is of interest. Surface hardness seems to be dependent on the particle size of the precipitated nitrides. The optimum particle size (and therefore maximum hardness) is apparently obtained at the lower temperature.

Case Depth — Figure 1 shows a curve of time versus case depth for nitriding temperature 965 to 975° F. The "case" represented by this curve is the layer down to the place where the hardness equals the core hardness. This graph represents the average depth that may be expected under these conditions on Nitralloy steels (Nitralloy-N excepted) and was drawn from data compiled from a number of installations. It agrees very closely with the curve previously published by V. O. Homerberg in his pamphlet on "Nitralloy and the Nitriding Process".

There is a variation between the case depth as shown by the hardness gradient, by visual examination of the fractured sample, and by some etches. The fracture sometimes shows a case as much as 0.004 in. shallower than the actual case as shown by the hardness-depth curve. The depth of the polished and etched case depends on the etchant. Nitric acid in alcohol (nital) is often used, and although it gives the full case depth as above defined, the line of demarcation between case and core is often indistinct unless the strength and time of etching are closely controlled. Marble's reagent (cupric sulphate) is sometimes used, although erroneous depths are indicated if the etching is too long. For any etchant, a procedure should be worked out which is known to agree with the hardness gradient.

A two-solution etch for showing case depth has been successfully used on some of the research work on nitriding at Massachusetts Institute of Technology, as follows:

SOLUTION No. 1:
- 1 gm. HgCl
- 20 ml. conc. HCl
- 80 ml. ethyl alcohol, 95% or absolute

SOLUTION No. 2:
- 10 gm. $MgCl_2$
- 1 gm. $CuCl_2$
- 40 ml. conc. HCl
- 100 ml. ethyl alcohol, 95% or absolute

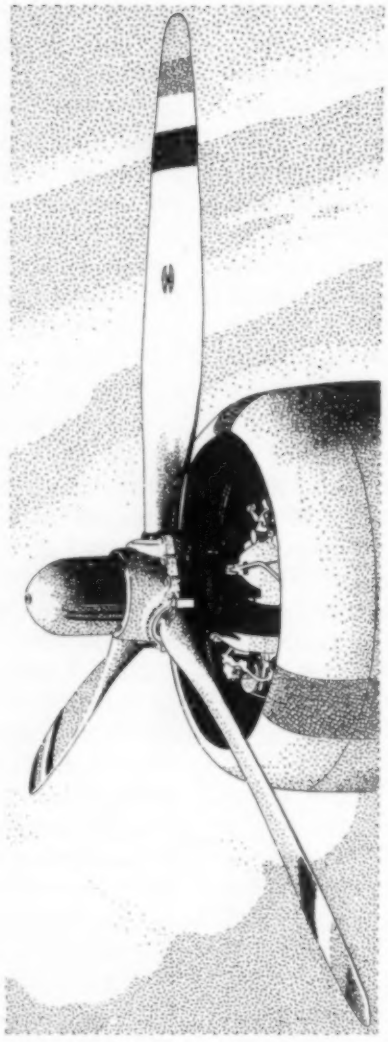
Dip or swab sample for 10 sec. in Solution No. 1; then dip or swab in Solution No. 2 until the case depth is revealed. The case etches light and the core etches grayish brown. The etch in solution No. 2 should not be too long.

So far no procedure other than higher temperature has been found to increase appreciably the nitride penetration in a given length of time. A two-heat cycle consists of 950 to 975° F. for 10 to 20 hr. depending on the desired hardness, followed by 10 hr. or more at 1050° F. for the case depth desired. This has been practiced by

a few with apparent success where extremely high hardness is not necessary. Some who have used this cycle say that the same case depth with only slightly lower hardness can be obtained by nitriding at 965° F. for 15 hr. followed by 1050° F. for 10 hr. as is obtained by holding 40 hr. at 975° F. Although this two-cycle operation does effect appreciable savings by increasing the number of heats per week, it does not save any ammonia since, if the same dissociation is maintained at the higher temperature, consumption per hr. will then increase as much as 100%.

Pressure — Mention should also be made of the effect of pressure on case depth. Experience has indicated that a gas pressure of at least 1 in. water gage should be held on the work container at all times. Slightly higher pressure — of the order of 2 or 3 in. — apparently has no appreciable effect, while experience at one nitriding installation indicated that pressure under 1 in. resulted in a little shallower case. Pressure is usually maintained simply by bubbling the exhaust gases through 1 or 2 in. of oil or water. Oil is generally preferred, since moisture-laden gases passing out through the exhaust line may result in condensation troubles, especially in winter. Mercury must not be used in the bubble bottle, since mercury and ammonia constitute an explosion hazard.

Moisture is often produced in the retort itself and is carried out into the exhaust line and bubble bottle. Ammonia of course breaks down into hydrogen and nitrogen, and hydrogen, at the furnace temperature, reacts with oxygen (infiltering air) or with oxides (scale or rust) to form moisture. Even freshly machined steel adsorbs oxygen at the surface which reacts with the hydrogen. Likewise, any air that has not been flushed out of the retort prior to coming up to temperature or any air leaks during the cycle produce moisture. The hot gases carry the moisture into the exhaust line and bubble bottle, where the water condenses. In laying out nitriding installations it is therefore helpful to provide drains at the low points of all exhaust lines.



Effect of Surface Condition — Since the ammonia consumption rate, other factors being equal, is based on surface area, obviously a rough surface will have a greater effective area and therefore consume ammonia at a higher rate than a polished surface. This is apparently the explanation of the fact that several installations nitriding "Nitricast-iron" at 965 to 975° F. which we have checked appeared to be using as high as 50 to 80 cu.ft. of ammonia gas per hr. per 100 sq.ft. of nitrided surface (dissociation at 30%).

Since surface scale is flaky and porous, parts having a scaled surface consume excessive ammonia, as would be expected. In nitriding, the scale peels off, actually exposing more reacting surface. A decarburized surface has somewhat the same effect, in that it tends to blister and peel, thus increasing the reacting area.

In a number of instances it has been noted that the ability of a part to nitride properly is dependent on its surface finish. Although difficulties have been encountered in the laboratory in trying to duplicate the conditions, it has been evident in several instances that a burnished or a highly polished surface will not nitride satisfactorily. To overcome this possibility some metallurgists sand blast the surfaces to be nitrided, while others bonderize them. Either practice produces a rougher surface on the part which nitrides more uniformly, and is therefore to be recommended.

The rate of ammonia consumption during nitriding increases as the operation proceeds. The nitrides formed apparently act as a catalyst in dissociating more ammonia so that, as the amount of surface nitrides increases, the rate of dissociation also increases. For this reason the average hourly consumption is less for a short nitriding heat than for a longer heat. This is also one of the reasons for allowing a higher dissociation during the latter part of the cycle, since there is a natural tendency for dissociation to increase. However, the figure of 20 to 30 cu.ft. includes the average hourly consumption for most lengths of nitriding heat.

Retorts — The material used in constructing the retort has a definite effect on the gas consumption. Since ammonia in contact with iron or low alloy steel dissociates at operating temperatures, the retort cannot be made of these materials. Sheet iron or plain carbon steel, if used, will nitride and the brittle case will spall off; the retort deteriorates and uses up ammonia needlessly, especially since these nitrides actually catalyze and increase the dissociation rate. To block off this effect, plain carbon steel retorts are coated, or high alloy materials are used. Coating usually takes the form of a porcelain enamel, which works very well except for its tendency to spall off from blows. However, if handled carefully porcelain enameled retorts give satisfactory service especially where only small light weight parts are to be heat treated. Spalled portions can be refinished by sand blasting, painting with a chromium oxide and sodium silicate, and drying at around 250° F. Smaller retorts are sometimes made of plain carbon steel and coated completely with this paint, although it is usually necessary to recoat them at regular intervals.

Alloys are usually used for retort construction. A 25-20 nickel-chromium alloy is about as low in nickel as is usually employed, while 35-15 is quite common. Inconel as well as 62-13 nickel-chromium alloy has been used extensively with good results. Retorts of Inconel have been under constant use for as long as ten years and are still in good shape and apparently low in ammonia consumption.

The lower alloy retorts apparently nitride slowly and, although they stand up well, they do seem to increase ammonia consumption to some extent. Nitriders having combination nitriding and carburizing units equipped with lower alloy retorts have found that a carburizing heat breaks down the nitrides and decreases the ammonia consumption. This is generally done every six to twelve weeks. The same results may be obtained by heating the retort and fixtures up at least to 1400° F. (preferably 1600° F.) for several hours with oxygen-free gas passing through. The nitrides apparently break down at a rate depending more or less upon the temperatures used. Actually if the retort and fixtures are in good condition — in other words, not nitrided or "poisoned" — it is possible to pass a few cubic feet of ammonia gas through the empty nitriding retort at the nitriding temperature (under 990° F.) without dissociating more than 5 or 10%.

There have been some indications that air has a harmful effect on alloy nitriding retorts and fixtures, at least those made of 35-15 nickel-chromium, at nitriding temperatures. It was noted that when such retorts were exposed to the air by pulling the heat while at the operating temperature, the ammonia consumption increased appreciably for the following heats. It is therefore suggested that, wherever possible, retorts should not be opened to the air when hotter than 400 or 450° F.

Other Means of Reducing Ammonia Consumption

Obviously any ammonia lost through leaks in the retort seal, piping joints, or valve stems, will increase consumption. However, these leaks, although irritating, do not amount to many pounds. Actually, a concentration of only 53 parts per million, by volume, of ammonia gas in air may be detected by odor; 400 parts per million will irritate the throat, and 700 parts per million will irritate the eyes.

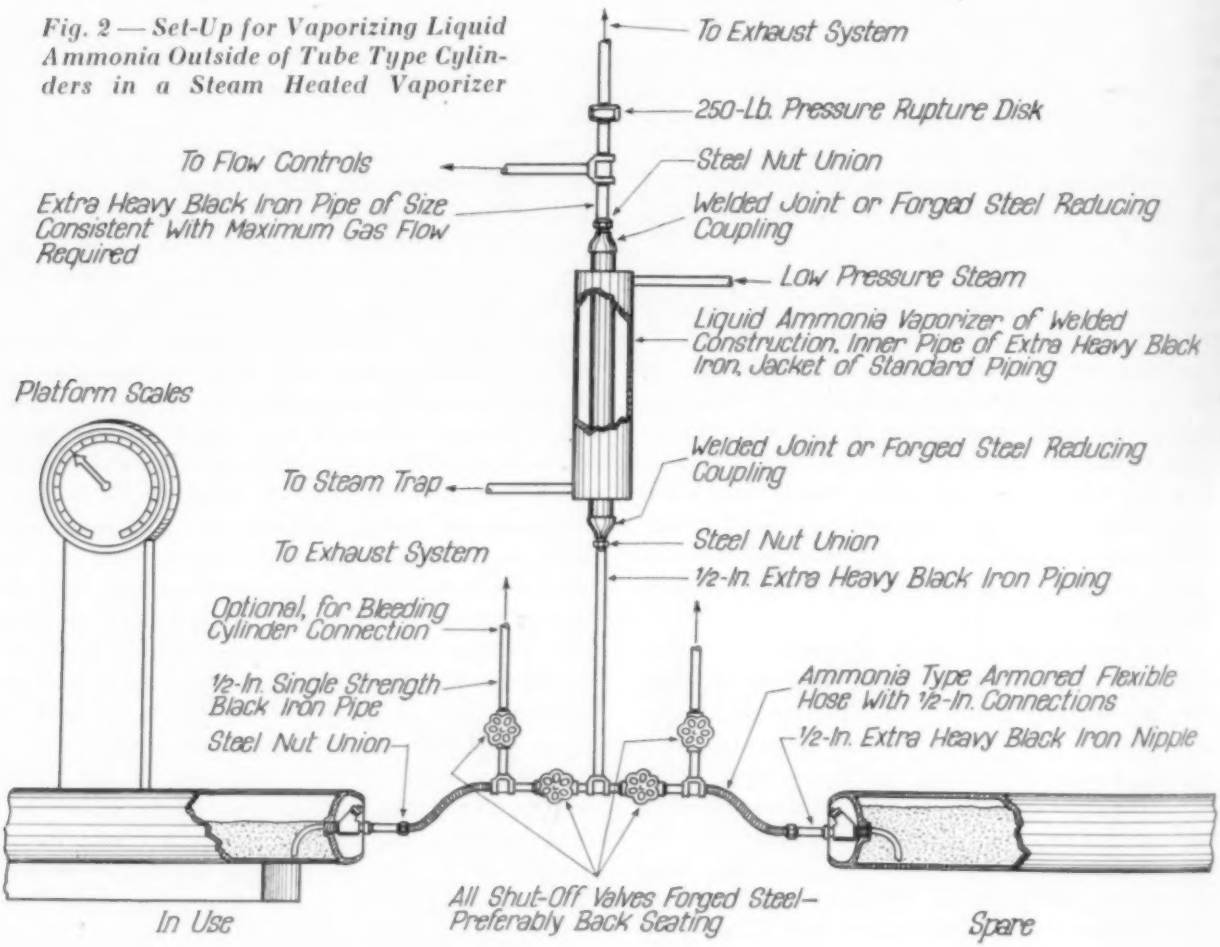
One practical suggestion is to wipe off, periodically, the grayish-black soot which collects on the fixtures and parts of some furnaces. The source of this soot or its entire effect is not entirely understood, but it does increase the rate at which ammonia dissociates.

Another economy may be practiced where there is more than one furnace. The exhaust gas from one furnace may be used to flush out a loaded retort before bringing it up to heat, or it may be used as atmosphere during cooling. No matter whether exhaust gas or pure ammonia gas is used, it is good practice to cool down to about 350° F. in an oxygen-free atmosphere. Ammonia is then often blown out of the retort into the exhaust line by attaching an air hose onto the ammonia inlet, thus eliminating this source of ammonia fumes in the building. If air enters before the parts have cooled properly, or if it leaks during the heating cycle, a characteristic purple or rainbow-hued discoloration results. This discoloration is not generally considered harmful, nor necessarily indicate faulty nitriding.

An ammonia wastage quite obvious to the gas manufacturer is the return of a few pounds of liquid in supposedly empty cylinders. This is of no value to the ammonia manufacturer since it cannot be economically reclaimed. As thoroughly discussed in an article entitled "Handling of Liquid Ammonia for Nitriding and Other Atmospheres" in *Metal Progress* for February 1943, the maximum amount of gas that may be expected without the cylinder "freezing up" under average conditions is 25 to 30 cu.ft. of gas per hr. from a vertical cylinder or 45 to 50 cu.ft. if horizontal. If gas is withdrawn at an appreciably higher rate, heat will not be absorbed by the

cylinder rapidly enough under most conditions to supply the heat of vaporization; the temperature of the cylinder will fall and will, of course, be accompanied by a drop in pressure, eventually indicating that the cylinder is approaching dryness. Since the maximum heat transfer takes place through the portion of the cylinder walls in contact with the liquid ammonia inside, it is obvious that the rate the gas may be withdrawn continuously will decrease as the cylinder is emptied. Therefore, attempting to withdraw ammonia too rapidly may result in a pressure so low that it is thought to be empty whereas it still contains considerable ammonia.

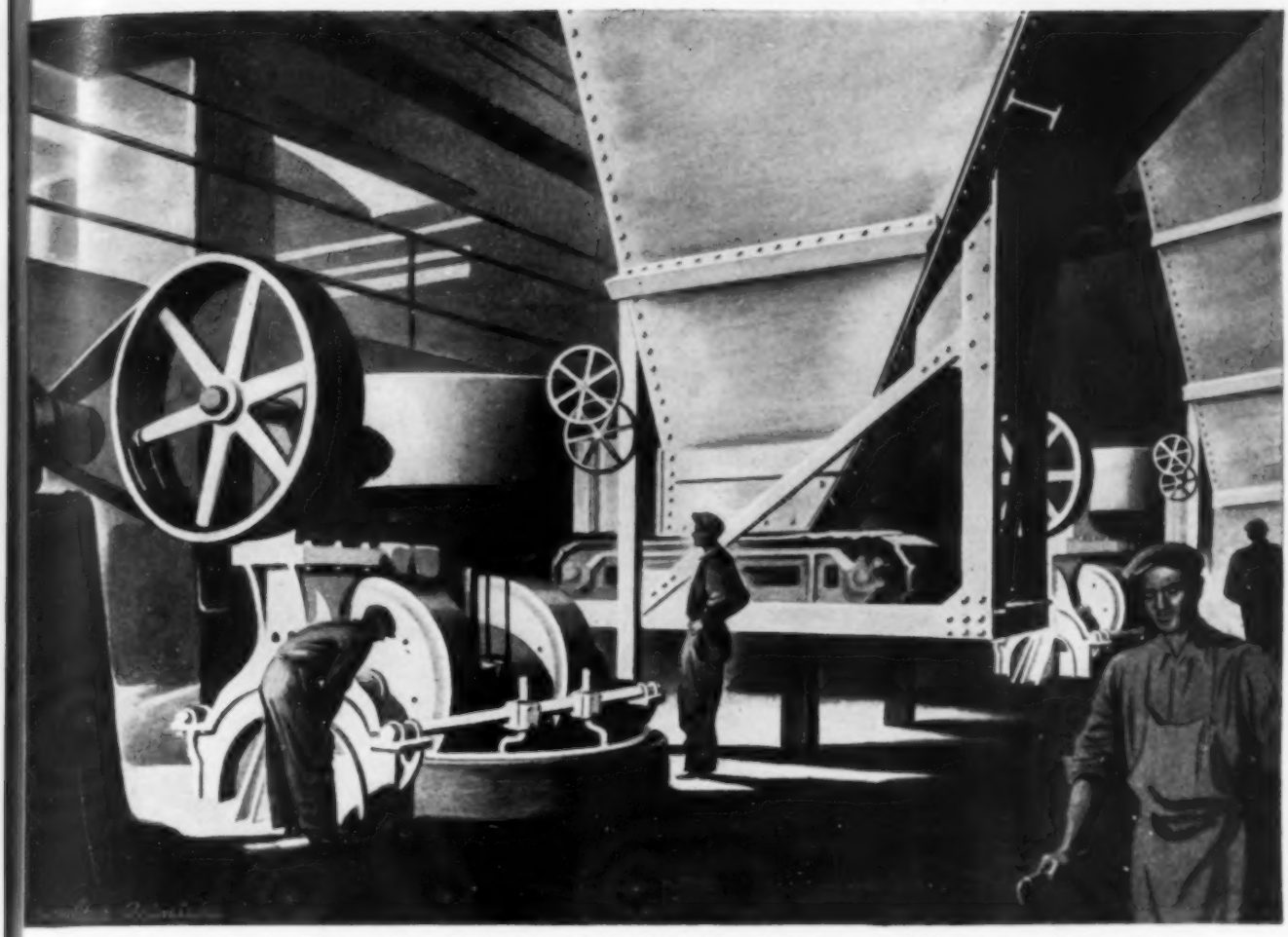
Fig. 2 — Set-Up for Vaporizing Liquid Ammonia Outside of Tube Type Cylinders in a Steam Heated Vaporizer


To Exhaust System
250-Lb. Pressure Rupture Disk
To Flow Controls
Steel Nut Union
Extra Heavy Black Iron Pipe of Size Consistent With Maximum Gas Flow Required
Welded Joint or Forged Steel Reducing Coupling
Low Pressure Steam
Liquid Ammonia Vaporizer of Welded Construction, Inner Pipe of Extra Heavy Black Iron, Jacket of Standard Piping
Platform Scales
Welded Joint or Forged Steel Reducing Coupling
To Steam Trap
Steel Nut Union
To Exhaust System
½-In. Extra Heavy Black Iron Piping
Optional, for Bleeding Cylinder Connection
½-In. Single Strength Black Iron Pipe
Ammonia Type Armored Flexible Hose With ½-In. Connections
Steel Nut Union
½-In. Extra Heavy Black Iron Nipple
All Shut-Off Valves Forged Steel—Preferably Back Seating
In Use
Spare

Piping and Cylinder Set-Ups

Inasmuch as each 100 sq.ft. of surface being nitrided may be expected to consume up to 30 cu.ft. of ammonia gas per hour, it will be seen that for economical gas consumption at least one cylinder in the vertical position should be connected to a furnace nitriding loads having in the order of 100 sq.ft. of surface, while one cylinder placed in the horizontal position may be expected to deliver enough ammonia gas for furnaces nitriding up to 150 sq.ft. of surface. For furnaces with larger loads, a proportionate number of cylinders should be manifolded on a common header supplying ammonia gas to the furnace. For continuous operation it is customary to connect a duplicate battery of cylinders to turn on when the first battery is exhausted. This is clearly shown in illustrations in the *Metal Progress* article above mentioned. That article also gives a piping diagram reaching from vaporizer to consuming equipment, consisting (in order) of a liquid trap, a high pressure gage, pressure reducer, low pressure gage, flow control valve, visual flow meter, and oil-sealed safety blow-off.

Figure 2, herewith, shows a set-up for vaporizing liquid ammonia outside of the cylinder in a steam heated vaporizer. If the latter is designed for sufficient heat transfer capacity, the limitations noted above for vaporization within the gas bottle or cylinder do not apply. The system, if properly constructed, is simple and foolproof and may be designed to furnish continuously any amount up to the maximum quantity of gas that would ever be required.



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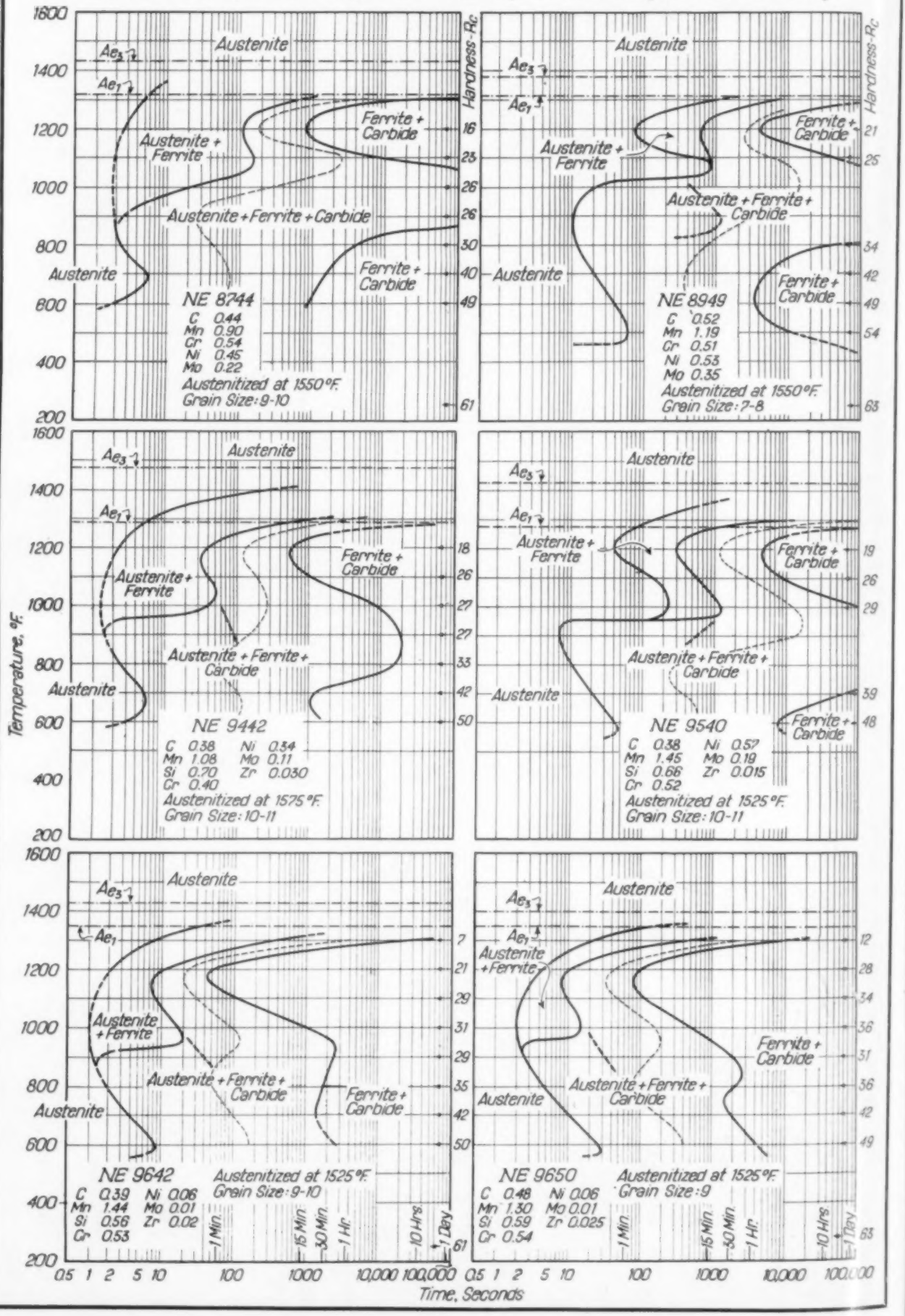
S-Curves for Six NE Steels

Isothermal Transformation Diagrams Determined by U. S. Steel Corp. Research Laboratory



Critical Points

By the Editor

MANY PROPHECIES are best buried and forgotten, but now and then a veracious one is worthy of remembrance. Consider the following prophecy as to the available monthly capacity for steel plate production in the U.S.A. and the actual production (average monthly) from July 1942 through February 1944:

	Prophecy	Actual
Universal plate	210,000 tons	122,350 tons
Sheared plate	430,000	452,850
From converted strip-sheet mills	445,000	531,650
Average, per month	1,085,000 tons	1,106,850 tons
Estimated needs	710,000	

The prophecy was by Arthur G. McKee, in an estimate made for Jesse Jones to guide Government policy in financing new rolling mills, and was published in *Metal Progress* for December 1941. Most of the intervening expenditure has been to adapt strip-sheet mills to plate production by installing slab heating furnaces, transfer tables, shears, and handling equipment. Production hit a practical maximum in mid '42 and has been steady ever since; the figures in the second column were recently released by War Production Board. ....This is but a part of the truly magnificent response of steel makers, from bosses in the front office down to laborers in the ladle pit, to a wartime demand for all the metal that could be made. This has been done by the steel industry, despite the loss of 30% of the staff — including a far larger proportion of the younger and more vigorous men — to the armed services.

I told you so

PLATE PRODUCTION and shipbuilding are Siamese twins, and if any part of America's performance as the Anti-Axis Arsenal has caught the amazed eye of the statistician, it is the rate at which we have built ships. Even more notable, to the engineer, are such things as the complete design and production, together with a special power plant, of sea-going landing craft in five months — a performance equally as meritorious as the 40-day average time for standardized Liberty Ships, keel laying to delivery with steam up and holds open for cargo. Production records of non-combatant ships of over 1000 tons dead weight show steadily rising figures for ships, more in number, greater in size, and (what is not shown in the average) better in speed, and more diverse in specialization:

Production line manufacture of ships

Summary of Eight Years of Shipbuilding

World War I*			World War II†		
Year	Number	Tonnage	Year	Number	Tonnage
1916	70	572,800	1940	...	637,900
1917	135	985,400	1941	103	1,160,900
1918	440	2,720,100	1942	746	8,090,000
1919	725	5,510,750	1943	1896	19,238,626

*Fabulous Hog Island Included
†Fabulous Kaiser Enterprises Included

As to how we got that way, no less a personage than President Roosevelt has written, in a letter to Prime Minister Churchill concerning the "sail-away" delivery of American ships by British crews, "There has been developed a welding technique which enables us to construct standard merchant ships with a speed unequaled in the history of merchant shipping." The welding industry can thereby rightfully preen itself. (Ships are not all; use of welding in all kinds of ordnance and munition making has been equally

impressive; maybe it can be measured in consumption of electrodes, which jumped five-fold from 100,000 tons in 1940 to a half-million in 1943.) A candid observer would, however, have to acknowledge that something else besides the change from a riveting hammer to an electrode holder is responsible for such records as 24 vessels a month out of an 11-way yard. This something is production management whereby the ship is built elsewhere in sections and only assembled on the ways.....INTERNAL STRESS NOTE: "Only three per cent of the welded ships have developed cracks" says an official statement designed to be reassuring. *Only* three in a hundred! Nearly all discovered and patched up before disaster. An organized attack on the problem is under way, but progresses slowly; seven years after the Engineering Foundation organized its Weld Stress Committee it has merely mapped an intelligent campaign. Realizing that the physical behavior of metal varies with the type of imposed stress system, this committee is now attempting to find some means of preloading a simple structure with known multiaxial stresses, and then measure the residue of strength available for useful work.....INTERNATIONAL NOTE: Admiral Vickery of the Maritime Commission, commander of shipbuilders, says the British are making ships in fewer man-hours than we do, largely because no-one spends much time on labor relations, share-the-ride plans, safety drives, and other schemes to make life easier for the productive workers. Over there prefabricating is practically unknown, and welding is limited, as compared to our standards.

Mass production of aircraft

TO THIS non-nautical observer, the amount of lost motion and plain loafing in the few American shipyards he has seen is nothing less than scandalous. He wishes he could present some figures paralleling those recently issued by the West Coast Aircraft War Production Council: By new devices, by better management, and by more skill by workmen, a four-engined bomber which required 70 man-years to construct in late 1941 required 17 man-years in 1943. Limiting the consideration to air frame alone, the direct labor per pound of finished weight was reduced from 1.67 to 0.87 man-hours — just about one-half — during the calendar year of 1943. Equally illuminating is the production record for one of our best fighters: The first plane required 157,000 man-hours; the 10th, 59,000; the 100th, 26,500; the 1000th, 7800 man-hours.....Maybe, though, these notes are getting too statistical; anyway, the Fortresses have been flying east all morning, over where I now sit writing, at five-minute intervals.

AS FOR the relatively few shirkers, take the following by Elsie Myers, from Ted Robinson's column in the Cleveland *Plain Dealer*. The last line is tragically true.

Before Swine

Oh I hear them bellowing about taxes
and snarling over meat,
whining about gasoline and liquor and a shortage of needlepoint,
striking, striking, striking
for better and more of it —

I see them dodging the draft with the skill
of pigs in a pen,
slick and quick and very smelly.

And it is to make the world safe and soft for them
that I am nailed to a cross
and my son is "missing in action".

Victory on the metal front

THINKING that no end of credit should be given to a group of straight-shooting Americans in the War Production Board for our favorable position as to supplies of essential metals and alloys. (One hesitates to name a few of these men, for fear of invidious comparisons.) Two years ago the list of critical items — whose supplies were inadequate for war and for most essential uses — included nearly all of the steel alloys, the tool materials, the light metals and most of the other non-ferrous metals. Many were the strenuous efforts to import the scarce ores, to develop American mines, to enlarge smelting, refining and fabrication plants, to preach and practice economy in use. The fruits of this planning are fairly well known; the critical list now contains only tin and nickel of the common metals. Some mill products today are scarce due to man-power or facility shortages; these are malleable iron, seamless steel and copper tubes, plates and rails, and numerous light brass products. All the rest are sufficient and *available* for meeting essential war and industrial demands. Truly an amazing two-year performance! It would be well to remember this victory in the future, when some sharp-shooting politician or muck-raking publicist starts slinging mud at some of these public servants, yelling about a mistake here and there, a stock pile larger than actually needed, some plants that never were finished or operated, some earnest and expensive effort that bogged down with no result. The record of grand achievement is what should count in the final verdict. They delivered plenty of metal, on time!....STATISTICAL FOOT-

NOTE: Tin is still very short. It is the only metal that is scarcer today than before Pearl Harbor. Only our pre-War stocks have prevented delay in supplying essential military needs, and the stock pile is continually shrinking. In fact, mine production of areas now open to the United Nations is also actually decreasing. As to nickel, Canadian production has been steadily at capacity (285,000,000 lb. per year) for the last three years. Metal available to the United States in all forms and from all sources was more than twice as much in 1943 as in 1939.

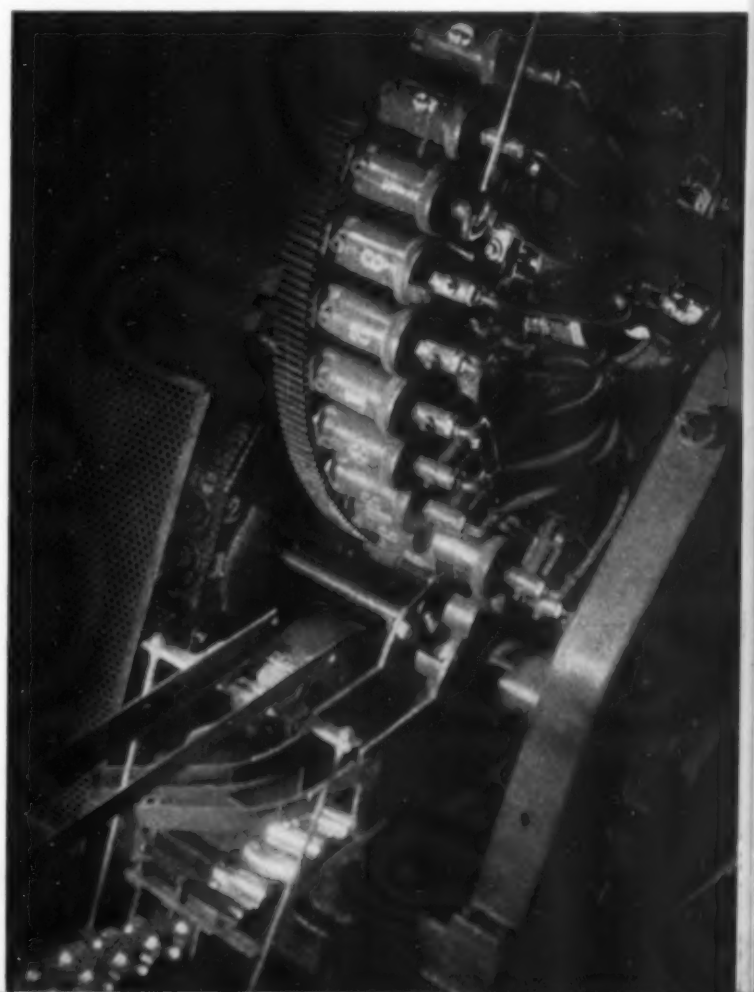
POKING good-natured fun at the ring-around-a-rosy motion which often accompanies straight-line progress, Howard Fritz, director of research of the B. F. Goodrich Co., cited the dehydration of food, necessary to save tin cans and shipping space. That, in turn, has required millions of steel containers for germ-free water to be used by soldiers on the march. Neatly quips Fritz: "So we build dehydration plants to take the water out of food so we can take the food out of cans, so we can put water into the cans we took the food out that we took the water out of."

Cans in wartime

Which reminds me that a brochure "American Can Co. in Wartime" is as interesting a document as you can read. Prepared for use in renegotiation of the company's war contracts, it shows how a progressive, specialized concern can adapt its organization and facilities to the strangest wartime needs. (United Shoe Machinery Corp. is another outstanding example known to me, and doubtless there are dozens of others.) Modification of the entire can-making industry to save scarce tin was a prime job; here an enormous reservoir of information built up over the years concerning substitute materials, testing techniques, and manufacturing equipment was put into instant service. Accumulated knowledge of the corrosive action of foodstuffs and quick (10-sec.) corrosion tests gave reliable answers to such questions as what can be packed in light tinplate, in steel with phosphate coatings with or without lacquering, or in fiber. Tin in solder and coating on a "standard" can was rapidly cut to one-fifth the old requirement; even a tin-free can may now be made in mass production (at a price). Machinery for making containers required in hundreds of shapes and sizes by the Army and Navy, medical corps and aircraft, has been turned out promptly. Robots have also been adapted to other operations, like electronic safety stops on press equipment for cartridge links and cartridge cups, to indicate a failing die when it is just starting to make scrap. But it doesn't stop there. Ability to make specialized machinery put American Can into heavy manufacture of breech-block gages and fixtures, torpedoes and gyroscopes.

SO HAVE BEEN impressed, times without number, at the Army-Navy E awards to concerns that have utilized, for war production, each its great fund of stored information, of research already done on items and methods of peacetime. Some of these have already been described at length in *Metal Progress*, like the steel industry's design of the National Emergency alloy steels, the Aluminum Co. of America's utilization of low grade bauxite, the Dow Chemical Co.'s winning of magnesium from the ocean, the Ohio Crankshaft Co.'s application of electricity to all sorts of differential heating. Equally meritorious and more in the public eye is the Bell Telephone Co.'s application of electronics to radar and identification of targets, Western Electric's adaptation of telephone equipment to field command sets and "sound powered" phones, the oil and tire industries' chemical knowledge about rubber substitutes, the General Electric Co.'s development of the gas-impulse turbine, the chemical industry's improvements in explosives and plastics. Research pays the nation!

Research pays the nation



Incomplete Quenches

A group discussion on "Advanced Quenching Practice" was held at the last general convention of the ASM. Of the talks given by the experts at that time, the following three relating to the principal methods of incomplete quenching are available for publication.

Timed Quenching

By Muir L. Frey
Aircraft Metallurgist
Packard Motor Car Co.
Detroit

TIMED QUENCHING is an old practice in heat treating. It is used principally to prevent breakage during or after hardening of both carbon and alloy steels. It has been familiar to tool hardeners for years and continues to hold a very important place in tool treating technique. Its usefulness in other fields is increasing at the present time because the process is, in the light of recent research, much better understood.

The process is used in two ways. In the first, older, and somewhat cruder way, the part is quenched in a suitable medium to an appropriate *temperature* (which now appears to be below the nose of the S-curve) and is then withdrawn from the quenching bath and allowed to cool in air. No tempering operation is used; instead, an important part of the process is that there be sufficient residual heat in the parts to temper them automatically. It is obvious that a close control of final hardness cannot be obtained from this rule-of-thumb method, and it is subject to a large number of variables which make its application a matter of continuous cut-and-try. However, it is still in use in many places where more precise results are not required.

The second method and the one now most generally used consists of starting the quench of the piece in the proper conventional medium. Under ordinary circumstances a normal quench would result, but in this case quenching is stopped by withdrawing the work from the bath before it has reached bath temperature. The work may then be cooled in air or placed immediately in the tempering furnace. The remainder of this discussion applies to this method of timed quenching.

Recent research on transformation processes and rates has provided us with much information about the mechanism of this second process, known as the timed quench. As indicated previously, it is started in the same manner as a conventional quench; that is, the parts are quenched into a medium that will provide a cooling rate sufficient to suppress all reactions above the nose of the S-curve. Cooling in the quenching bath is carried out in the normal manner until some point well below the nose of the S-curve is reached. This point is usually that at which the formation of martensite starts, generally in the range of 350 to 600° F. The piece is then withdrawn from the bath and cooled in air or, when further precautions are necessary to prevent breakage, may be placed directly in the tempering furnace. The net result of this procedure is to reduce the rate of cooling through the range where martensite forms, and therefore to also reduce the rate of martensite formation. This fact is the key to the success of the procedure, the reasons being as follows:

It has been known for a long time that when martensite is formed there is an increase in volume. Since parts cooled in a liquid medium are cooler on their outer surfaces than at the center, this volume change takes place first on

the outside, and progresses toward the inside. The result is that there are residual stresses of considerable magnitude in the quenched parts, often exceeding the tensile strength of the material, whereupon it breaks during or immediately after quenching. It is obvious that there will be more trouble with pieces of non-uniform section than with those of uniform section.

It has recently been shown that in the common tool and constructional steels, once the formation of martensite is started, the driving force to complete the reaction is supplied by *drop* in temperature. It is reasonable to suppose then, that if the rate of temperature drop could be reduced, the rate of martensite formation would be reduced. In timed quenching this is done by taking the piece out of the quench immediately after the martensite reaction has started. The reaction will substantially complete itself, but at a slower rate, with the result that in any section the lag in transformation between the center and surface will be reduced, and so will the lag between the heavy and light sections. The result is less residual stress and far less breakage.

Other advantages in the process are, first, that the residual heat in the piece immediately tempers the martensite which was formed in the quench and second, that the piece is hot as it is removed from the quench and thus permits some approach to the isothermal type of transformation in the austenite that is retained in the piece as it comes from the quench. Both of these have the net effect of further reducing residual stresses. After the timed quench, air cooling alone is sometimes not sufficient to reduce breakage, and in those cases the parts should be transferred immediately from the quench to the tempering furnace where the martensite is certain to be tempered as fast as it is formed and usually to a softer decomposition product than can be had from the residual heat alone.

This method of quenching can be applied to carbon or alloy steels and to any liquid quench. Successful applications are:

1. Tools, such as water or brine quenched carbon steels for dies and complicated shapes.
2. Complicated shapes in high alloy tool steels.
3. Automotive parts of medium carbon or low alloy steels, such as collars, shafts and gears, which must be heat treated to high hardness yet which have both heavy and light sections.
4. Connecting rods; their combination of light and heavy section is frequently time quenched to prevent breakage.
5. Automotive axle shafts, in which high surface hardness is required, must frequently be time quenched to avoid cracking.
6. Ordnance parts such as flanged shafts, gear shafts and similar parts, usually with a combination of heavy and light sections, and made from steel of high hardenability.
7. Crankshafts of fairly high alloy steel (S.A.E. 4340) which are time quenched in caustic solutions.

Martempering

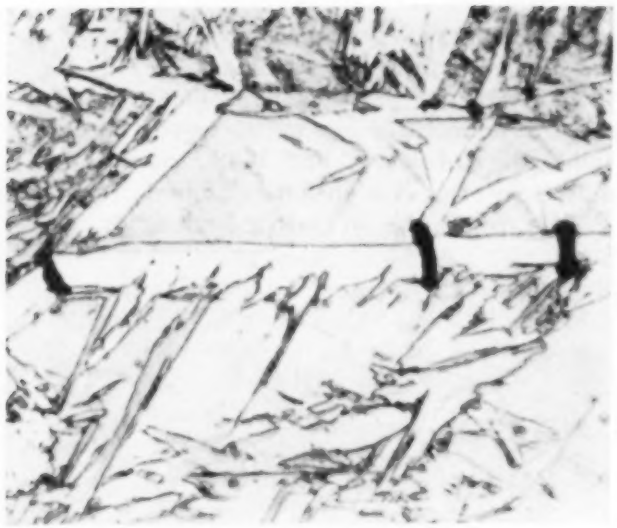
By Benjamin F. Shepherd
Chief Metallurgist
Ingersoll-Rand Co.
Phillipsburg, N. J.

THE MAXIMUM COMBINATION of strength and toughness can only be obtained in quenched and tempered steels by producing quenched structures that are 100% martensitic, free from tension stresses. No chain is stronger than its weakest link, and no martensite grain is stronger than the weakest constituent adjacent to it.

The strength and toughness which can be obtained from 100% martensitic structures is amazing — beyond the conventional relationships accepted as standard at the present time. The demand for the ultimate will only be met by recognition of this fact and adaptation of present practices to attain it.

The necessary changes lie in two directions. First, elimination of the chief offender — free ferrite. This can be done by use of higher carbon steels, thereby reducing the amount of hypo-eutectoid ferrite. The eutectoid can be lowered by increasing alloy content, achieving the same result. Higher quenching temperatures possible with fine-grained steels lead to more thorough formation of uniform austenite. Steel melting practices have a marked effect upon grain boundary ferrite and need further development.

The other change necessary is a realization that the quenching operation is all-important as to internal stresses. Since tension stresses must be absent, this phase controls the rate of transformation and the conditions under which martensite is produced. It can make or ruin the result.



Three Cracks Across a Martensite "Needle" (2000 Diameters)

What I have to say will briefly consider the second part, the quench and a particular method which I have termed "martempering". It consists of quenching in molten baths, held at a temperature about the start of the martensite transformation (the Ms point). It is to be assumed, of course, that the critical cooling rate has been exceeded.

Martempering is conducted for the primary purpose of forming a 100% martensitic structure that will be as free as possible from micro-cracks and high residual strains. These two gremlins cause more failures than commonly realized and are rarely tried and convicted of the crime. Micro-cracks are difficult to locate under the microscope and residual hardening strains cannot be seen.

While ordinary thermal strains often cause trouble, they are relatively unimportant compared to the strains set up in the latter part of the quench when cooling through the range from 700° F. to room temperature. This is where martensite forms. The exact temperature of the Ms point, or the formation of the initial martensitic grain, is a function of the carbon and alloy content and is practically unaffected by prior cooling rate and structure.

A large temperature differential is developed between the surface and interior of parts subjected to such intense quenches as in water or brine. The outside drops rapidly below the Ms point and forms appreciable quantities of hard martensite, oftentimes practically completing the transformation long before this reaction starts in the interior. Assuming that the cooling rate of the interior has exceeded the critical cooling rate so that martensite must form, the increase in volume when this happens will stretch the exterior so highly that failure often occurs.

On the slower oil quenches, the temperature differential for any given mass is smaller and the transformation stresses will be much less.

The dangerous portion of the operation for both types of quench, well recognized by the old time "practical hardener", is the portion from 400 or 500° F. to bath temperature. As pointed out by Mr. Frey in the preceding article, attempts are often made to reduce the danger in this region by interrupting the quench — removing the part from the bath after a certain time and allowing it to cool in air. He admits that the timing of such an operation is difficult from the practical production viewpoint. I would add that a compromise time is not suitable for parts having considerable section variations.

Martempering eliminates this danger. The bath temperature is high enough so that appreciable percentages of martensite do not form. The part is held in the bath long enough for the temperature to equalize throughout, then it is removed and martensite forms as the part cools slowly in air.

Fifteen Cracks — Count 'Em!

For practical reasons, we at Ingersoll-Rand have standardized on a bath temperature of 400° F. and holding times of 3 min. to 15 min. for sections up to 3 in. diameter. The maximum time in the bath is made a matter of practical convenience as no isothermal structure changes start at this temperature for a matter of hours.

With this practice, we extend the time interval over which martensite forms and make the rate similar to that found on the air hardening steels which are least susceptible to residual hardening strains. The martensite forms in the heavy and light sections, surface and center at approximately the same time.

It is surprising how long it takes for a part to cool from 400 to below 100° F. No attempt

must be made to accelerate this cooling or a temperature gradient will be re-established between surface and center, resulting in the very troubles we are endeavoring to avoid.

Consideration of this method must start with the quench. (This is not an added burden, for consideration should also be given to a conventional water or oil quench.) From the mass of the part we must estimate the cooling rate. From the estimated cooling rate we select a steel having a hardenability that will develop the desired as-hardened hardness — or, what is more important, desired structure with that cooling rate. "Selection of steel" is a phrase often used rather loosely. It means selection of a type of steel where the hardenability of any lot or heat received from the mills will not be less than that required by the job analysis.

In oil and water quenches we must also be careful to avoid steels with too high a hardenability or cracking will ensue. This consideration is not important in martempering.

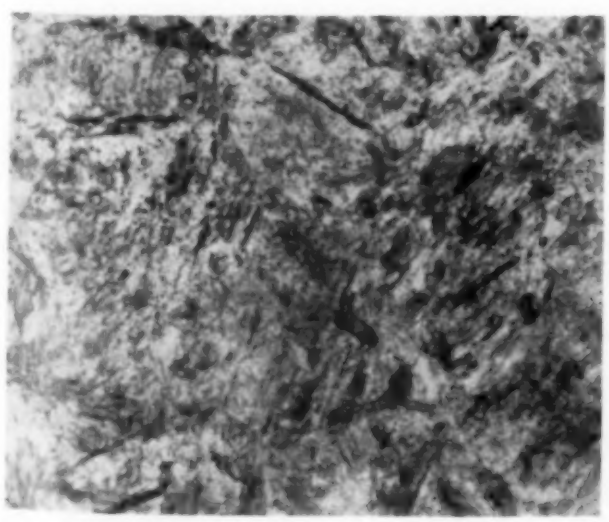
It can be readily seen that the process, like all processes, has limitations. Higher hardenability steels must be used for the same mass than for oil quenches, but oil quenches also require higher hardenability than water quenches. Steels with these higher hardenabilities can be produced and offer a promising field for the new "vitamin-treatments".

By using the quenching process outlined, we can produce martensite with a minimum of micro-cracks and residual strains. In our experience, distortion has always been markedly reduced over other quenches. After hardening, parts are washed in boiling water to remove the salt carried out from the quenching bath. This again is seldom an added expense, for oil quenched parts often require a special cleaning operation. If required, parts can be straightened immediately after removal from the salt bath and before further cooling, and will remain straight after the martensite is formed. This operation does not introduce objectionable strains as the steel is still soft and in the austenitic condition.

Martempering must not be confused with austempering which also calls for a quench in a bath at elevated temperature. In austempering, the time the pieces are held in the bath is based on that required for a desired microstructural change to take place, whereas in martempering the time required to equalize temperature is practically the same for all steels, being based on the specific heat of the metal at bath temperature.

In austempering, any appreciable percentage of martensite will defeat the object of the process whereas in martempering the aim is the production of 100% martensite.

Martempering is not new. Elevated temperature baths have been used for ages. The modern concept, however, is new, and that is that all the factors pertaining to the operation must be satisfied or it will be a failure. Steels cannot be indiscriminately quenched in molten baths or in any type of bath. Control of the transformation is obtained by the quench. Unless this operation is balanced and correlated to all the other factors, the result will be a failure.



These Are Not Cracks But Acicular Constituents (1000 Diameters)

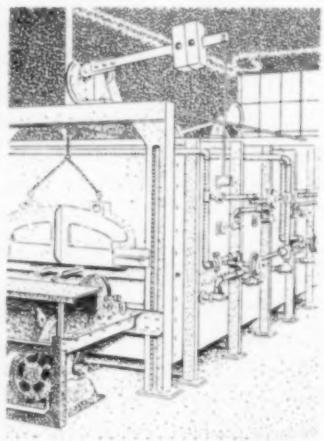
Hot Quenching and Austempering

By H. J. Elmendorf
Research Engineer
American Steel & Wire Co.
Cleveland

RECENT scarcity of alloying elements has been reflected in the change-over from the critical S.A.E. alloy steels to the leaner NE compositions. In many instances the S.A.E. steels of pre-war popularity were used without due regard to their intrinsic value of imparting improved hardenability and other special effects, such as improved impact strength at low temperature, improved ductility, improved corrosion fatigue, and so on. In many instances the plain carbon steel, within its limitations of hardenability, could and still

can be made to produce results equaling many of the alloy steel compositions. These results, in the heat treated state, may be produced by "hot quenching" carried on in any one of a number of ways. We wish to point out that we do not feel that a hot quenched plain carbon steel will necessarily excel an alloy steel properly treated in more conventional ways, but rather we believe that the method offers a possibility of producing "near-alloy steel properties" in a plain carbon steel, and this should be of prime importance in any economy.

The stresses induced by quenching are very apt to result in cracking. Many practices, such as time quenching, martempering, or immediate tempering after quenching, have been evolved to reduce quenching stresses to produce crack-free tempered steel. In the same manner, hot quenching will produce a crack-free steel; however, in general it should be recognized that immersion in a bath maintained at elevated temperature may produce a *slower* quench than usual room temperature mediums. Accordingly there may be some reduction in the size that can be fully hardened.* This drawback may be compensated for by recognizing the limitations of the process and making allowances accordingly. On the other side of the ledger, it has been found that hot quenching results in a minimum of distortion in the quenched part, a matter of definite value in so many applications.



In any discussion of "hot" quenching we should draw some loosely defined limit as to the range of quenching temperatures involved, so we will now confine ourselves to approximately 200 to 900° F. It is realized that this is rather broad, but the following remarks will probably warrant the selection.

Furthermore, the subject may well be divided into two sections which make use of two slightly differing cycles and entail a division of the wider quenching range into one consisting of 200 to 450° F., and one of 450 to 900° F. The first range of 200 to 450° F. may be identified as the region where mixed microstructures of austenite and martensite are found in the quenched piece, while the other range, 450 to 900° F., may be considered as the region of direct transformation of austenite to the acicular constant temperature product now commonly known as "bainite". Of a necessity these two ranges will overlap to a certain degree, the amount of overlap being dependent upon the chemical analysis of the steel.

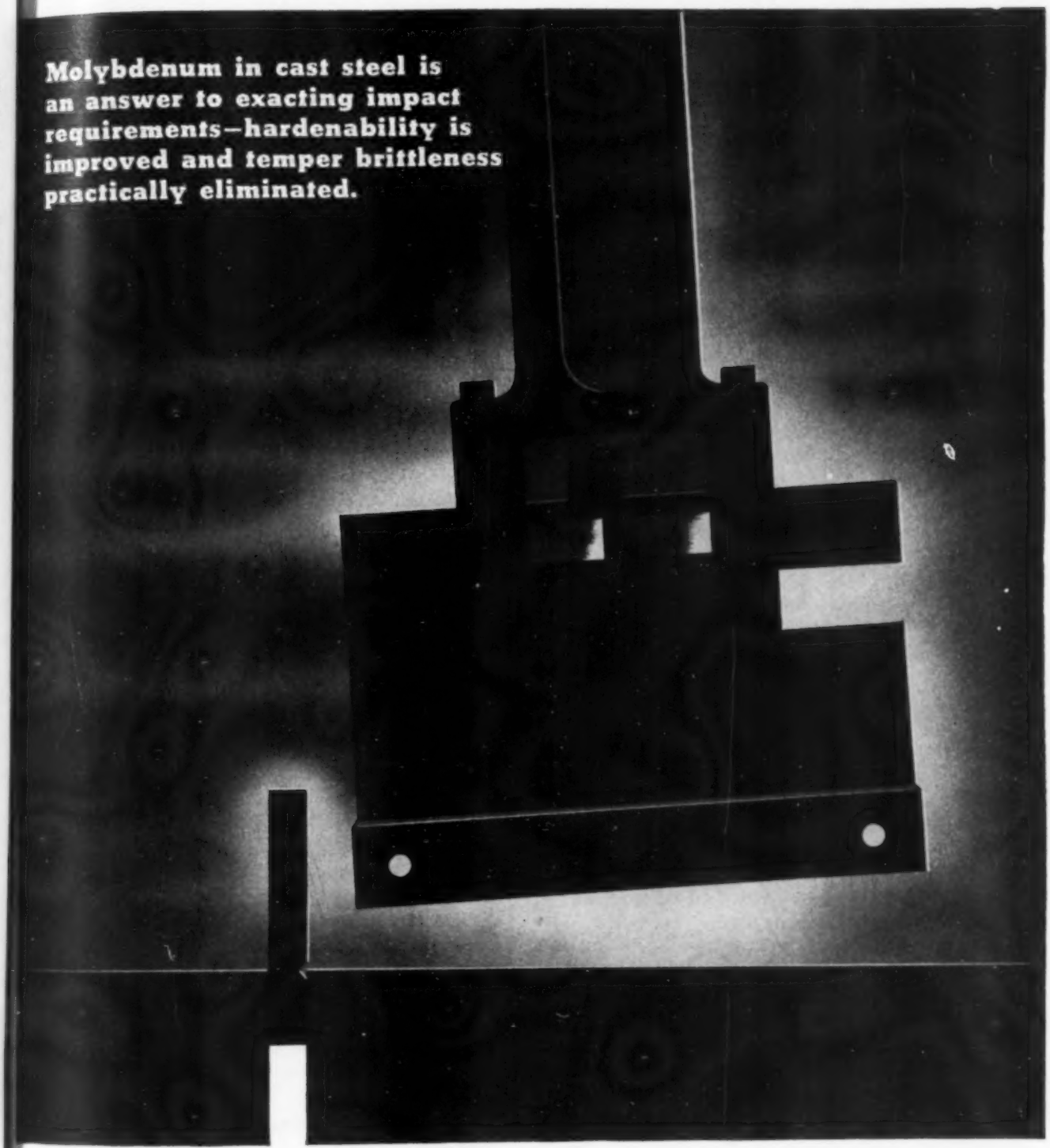
The temperature range for the direct transformation of austenite to bainite, namely 450 to 900° F., is generally recognized as the usual temperature range for the "austempering" method of heat treatment. Briefly, austempering is a heat treating method wherein the steel is converted into austenite by appropriate heating above the critical range and soaked at high temperature for proper diffusion to uniform solid solution, and is then quenched directly into some heat-abstracting bath, usually molten salt or lead, and allowed to remain in that bath until transformation of the austenite to bainite is completed. The desired combination of quenching time and temperature may be readily obtained from the now familiar "S-curve" for the steel under consideration.

Essentially, these S-curves are time-temperature diagrams depicting the effect of temperature upon the time required for measurable beginning and substantial ending of the austenite transformation. (The character and mechanical properties of the resulting microstructures are also useful adjuncts of these curves.) They act as a "road map" for the selection of the heat treating cycles in the austempering process. It should be recognized that every steel analysis has a very definite S-curve; however, sufficient curves are now available so that we are in a position to readily approximate the desired heat treating cycles for almost any steel to meet any hardness requirement. About 60 such curves are collected in the recently published "Atlas of Isothermal Transformation Diagrams" by the Research Laboratory, U. S. Steel Corp.

The advantages claimed for the austempering method of heat treatment are: *(1)* Improved ductility at high hardness, the ductility being measured by reduction of area and elongation in the tensile test, and slow bend tests. *(2)* Improved impact strength. *(3)* Freedom from distortion due to the slow transition from the gamma to the alpha phase. *(Continued on page 314)*

*Size also is limited by the mass that can be cooled, *to the very center*, past the nose of the S-curve by the hot quenching bath. In discussion, Mr. Elmendorf mentioned the following sizes as suitable in the austempering method:

Steel	Analysis	Size
C1059	0.60% C, 0.60% Mn	⅛ in.
C1062	0.60% C, 1.00% Mn	¼ in.
A4063	0.65% C, 0.90% Mn, 0.25% Mo	⅝ in.


Molybdenum in cast steel is an answer to exacting impact requirements—hardenability is improved and temper brittleness practically eliminated.

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MOLY

Incomplete Quenching

(Continued from page 312) *(4)* With suitable equipment, a remarkable uniformity of heat treated product. *(5)* Austempering is no panacea to improve fatigue resistance — normally this is a function of strength and surface condition rather than microstructure.

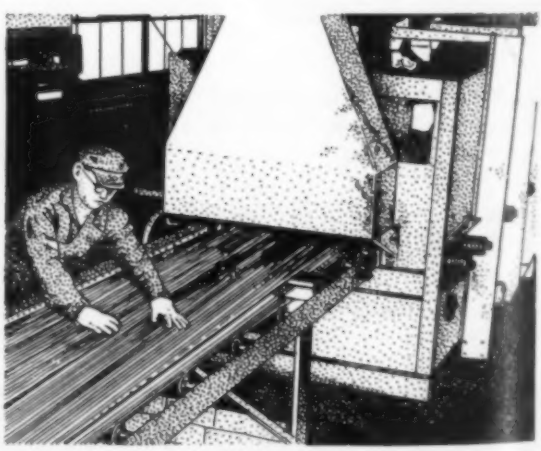
The quenching temperature range of 200 to 450° F., as stated before, may be described as the region of mixed microstructures (austenite plus martensite). The recent work on martensite transformations points out that martensite is produced on cooling through a range of temperature characteristic of the steel under consideration. That is to say, at some rather definite temperature austenite starts to transform to martensite, and this reaction progresses *as cooling proceeds,* until at some point the transformation is substantially completed. Of course the analysis of the steel has considerable bearing upon the temperatures involved and many steels, particularly of high alloy content, will not become wholly martensitic even when temperatures far below room temperature are reached. Some austenite may still be present.

It has been proven that the mechanism of the austenite-to-martensite transformation may be put to immediate use, in the sense that an adequately controlled quench temperature will result in a fairly controllable microstructure of martensite and austenite — the martensite, of course, resulting from the austenite transformation during cooling, the austenite being that amount which has not had an opportunity to transform. Now, any subsequent immediate tempering following the controlled quench will transform the remaining austenite to bainite by direct transformation, and will also temper the existing martensite. The proportions of austenite and martensite in the quenched steel may be altered by a specific change in the quenching temperature within the martensite formation range, and accordingly any combination of bainite and tempered martensite may be produced. It is readily apparent that increasing the quenching temperature — always staying within the range of martensite formation — will retain more austenite and will result in a richer bainite steel after tempering, and it may be possible to obtain any desired properties within the limiting range of 100% bainite and 100% tempered martensite by simple manipulation of quenching temperature.

Sufficient experimentation has been carried on to indicate tentatively that a heat treated steel with a composite microstructure of bainite and tempered martensite will benefit from the high ductility of the bainite and the high strength of the tempered martensite. Likewise it is known that the transformation time for the austenite remaining in the quenched steel is markedly shortened by the presence of martensite.

Therefore by a suitable control of the quenching temperature, based on a thorough knowledge of the martensite transformation, we are able to produce a controlled microstructure in our quenched steel and in so doing obtain very good mechanical properties. Inasmuch as we are making use of a hot quench followed by immediate tempering we are relatively free from the danger of cracking on quenching. Likewise very little distortion occurs, and the cooling rate on quenching nearly approximates the speed of a quench in oil at room temperature. It is believed that investigations in the field of ferrous heat treatment, in the near future, will be as much concerned with behavior during martensite formation as with any other single item. Unfortunately not much information is available at present on this subject.

In conclusion, we can use hot quenching in either of two categories, namely, direct transformation of austenite to bainite known as austempering, and the controlled quenching of steels to produce a mixed microstructure of bainite and martensite. Both have been found to do a very good job on carbon and low alloy steels. The equipment available, the time elements, and similar circumstances may be the principal elements in the problem of selecting the correct steel. It is believed that in these days of doing the most with the least, we might well take advantage of these results in hot quenching, and release the vital alloys to those uses for which they are definitely required.



BLAZING TRAILS IN THE SKY

Electric Welded Steel Tube by REVERE

ROCKET SHOWN HERE AS SECRECY IS ENDED

50-Pound Projectile Was Used Effectively in Invasion

Details of an artillery type rocket projectile, classified heretofore as secret, and used effectively in the invasion of France and on other fronts, were made public yesterday.

It was described by C. Donald Dallas, president of the Revere Copper and Brass, Inc., who announced that the projectiles produced at the Rome Manufacturing Company Division of Revere at its plant in Rome, N. Y., were being delivered in tremendous quantities.

The rocket projectile is comparable in potency to the famous Army 105-mm. artillery projectile, Mr. Dallas declared. He pointed out that the principle of manipulation and firing of the rocket projectile was similar to that of the "bazooka," except that the rocket gun used a light mount. He said the range and destructive force of the new projectile were far greater than those of the "bazooka."

"Rockets fired from landing craft and 'ducks' can lay down devastating barrages against hostile beaches in landing operations," he said. "They can be fired in salvos from airplanes and water craft whose previous fire power has been limited to smaller sizes of ammunition. They can be loaded with high explosives or chemicals and they may be used effectively to lay down a smoke screen to conceal military operations from the enemy."

Artillery-type Rocket Projectiles, which are being used with deadly effect against ground troops, ships, and even submarines, were developed by Revere at the request of and in cooperation with the U. S. Army Ordnance Department. The manufacture of these projectiles involved difficult research, the development of new principles of design, the application of new techniques and materials to withstand the terrific heat and pressure of the propelling charge. These facts have a real bearing upon your post-war plans.

We have been making electrically welded steel tube for 25 years. When war demands slacken, it will once again be freely available for mechanical uses, boilers, condensers, heat exchangers, water and steam lines, and similar purposes. When planning to use steel tube, remember Revere's outstanding success with the electric welding process.

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Personals

L. W. EASTWOOD, formerly with Aluminum Co. of America, is now assistant supervisor, Battelle Memorial Institute, Columbus, Ohio.

PAUL GOETCHEUS, formerly manager, Monel and Nickel Department, Steel Sales Corp., Detroit, is now manager, Fabricated Products Division, Michigan Steel Casting Co., Detroit.

E. R. MERTZ has resigned as chief metallurgist for the Bendix Aviation Corp. to organize the Mertz Heat Treating Co., Van Nuys, Calif., of which he is owner and general manager.

P. L. WILLSON, past chairman, Tulsa Chapter, formerly consulting engineer for Spartan Aircraft Co., is now consultant in matters of metals and processes for Halliburton Oil Well Cementing Co., Duncan, Okla.

C. H. LAGE, formerly vice president in charge of manufacture for Universal Unit Power Shovel Corp., Milwaukee, has been appointed general works manager of LaPlant-Choate Mfg. Co., Inc., of Cedar Rapids, Iowa.

GLEN DAVID BAGLEY of the Union Carbide and Carbon Research Laboratories, Inc., has been awarded the Jacob F. Schoellkopf Medal for 1944 of the Western New York Section of the American Chemical Society, in recognition of his leadership in the development and commercialization of processes for the production of active metals required for the war effort, in particular calcium and magnesium.

Promoted by Wickwire Spencer Steel Co., Buffalo, N. Y.: B. L. MCCARTHY, from chief metallurgist to assistant general superintendent of the Buffalo plant.

JOHN FRANCIS DRAKE, formerly chief chemist, and THEODOAR G. KENNARD, formerly assistant chief chemist and chief spectroscopist, Kaiser Steel Plant, Fontana, have organized the firm of Kennard and Drake, chemical and spectrographic laboratories, Los Angeles.

EDWARD J. P. FISHER has been appointed manager of sales for the Morrison Engineering Corp., Cleveland.

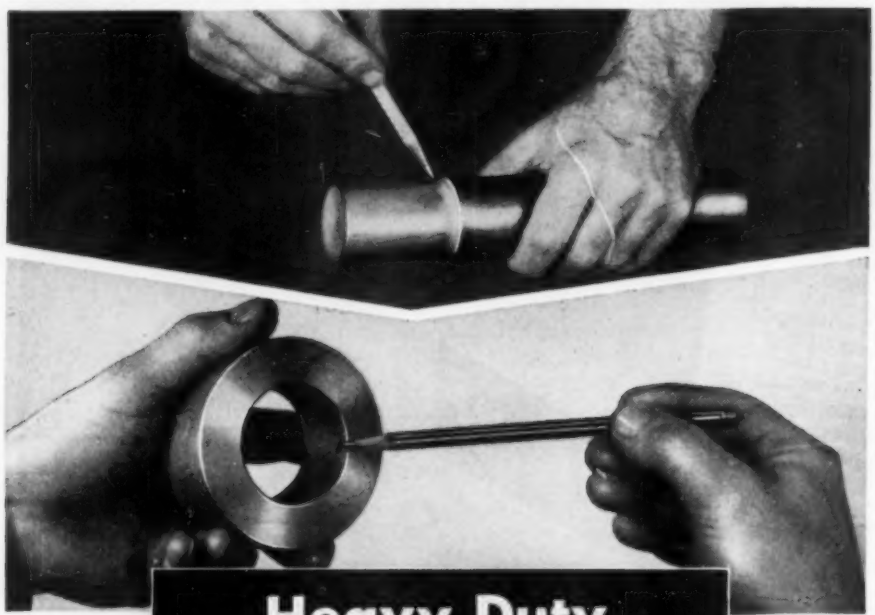
Promoted by Harvill Corp., Los Angeles: MAX POWELL, to vice-president in charge of technical research, also retaining his former duties as head of standard controls and chief metallurgist.

Promoted by Steel Improvement & Forge Co., Cleveland: CARL I. SCHWEIZER, from assistant metallurgist to chief metallurgist.

H. H. FULLER, formerly New York district sales manager for Bethlehem Steel Co., has been elected vice-president in charge of west coast activities.

HARRY I. ASKEW has been appointed district sales manager of the Universal Division, Detroit, for Universal-Cyclops Steel Corp.

EUGENE CALDWELL, general manager of the Hyster Co., Portland, Ore., has been elected a vice-president of that organization.



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Ampco-Trode coated aluminum bronze electrodes deposit weld metal comparable in strength, ductility, and bearing qualities with the various grades of cast Ampco Metal. This deposit can be applied to cheaper base metals to build up surfaces that resist wear, shock, and corrosion. Any grade of Ampco-Trode—selected for your required physical properties—can be welded to almost all metals and their alloys.

Illustrated above, are bearing surfaces overlaid with Ampco-Trode to increase wear-resistance. This same principle can be applied to many machine and tool parts where the problem of friction must be solved at low cost.

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"Okay, but who's going to pay for the X-rays?"

That's a good question; and one which you may ask, or be asked, soon in considering your postwar operations. The answer is simply this—in industry, generally, radiography more than pays for itself.

In your particular business, the cost-balancing savings may be, for example, in machining where radiography eliminates man and machine time spent on defective parts—

. . . or it may be in your foundry in the determination of most efficient casting technics;

. . . or in assembly, or molding, or welding, or inspection;

. . . or it may be in the design of your product itself which might be lighter or simpler, or capable of being produced by more economical methods.

Your cost accountants can reduce these savings to dollars and cents. In addition, there are other, less tangible, benefits—

. . . the sales advantages of lighter, sounder, surer products;

. . . the maintenance savings resulting from better performance;

. . . and the greater general good will of your products, and your company.

To help radiography pay its own way, Kodak supplies a line of special films, solutions, and accessories . . . and offers the experience accumulated in 17 years of research in this field. Eastman Kodak Company, X-ray Division, Rochester 4, N. Y.

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The Film tells the story

Personals

Appointments by the Midvale Co., Philadelphia: THOMAS RUTHERFORD, as manager of railroad and casting sales; TRUXTUN R. BRODHEAD, Philadelphia, district sales manager.

THOMAS P. WEST has been appointed vice-president and works manager of West Steel Casting Co., Cleveland.

EDWIN K. SMITH, metallurgical specialist, Science, Education and Art Division, China Section, Department of State, Washington, D. C., has been appointed to go to China to serve with the Chinese National Resources Commission.

HAROLD C. OSMAN, formerly sales manager of the Reading Steel Casting Division of the American Chain and Cable Co., Inc., is now sales manager of Crucible Steel Casting Co., Lansdowne, Pa.

HAROLD KING, former head of the metallurgical division of the engineering department of the University of Rochester, has been appointed chief metallurgist of the Anstice Co., Inc.

E. J. JOHNSTON, formerly service engineer for Shell Oil Co., has been appointed manager of the new Detroit district office of the National Rust Corp. N. J. MOLLHAGEN, formerly chief metallurgist for Motor Products Corp., is associated with Mr. Johnston as technical engineer.

Awarded the honorary degree of doctor honoris causa by the Escola Politecnica of the University of Sao Paulo, Brazil: ROBERT F. MEHL, director, metals research laboratory and head of the department of metallurgical engineering of Carnegie Institute of Technology, who recently concluded a four months' lecture series at the Escola Politecnica.

JOHN E. GAUS has been transferred from the V-12 to the V-5 program of the U. S. Navy, and has begun his flight training at Colgate University.

F. G. DAVELER has resigned as assistant chief engineer, the Drever Co., to become chief engineer of the Arcos Corp., Philadelphia, and has been appointed to the board of directors of Associated Industrial Engineers, Inc., Philadelphia.

MICHAEL J. MITCHELL has resigned from O'Brien Heat Treating Co., to join Powder Metallurgy Corp., Long Island City, N. Y.

FRANK K. METZGER, formerly divisional vice-president of Standard Steel Works Division, has been elected vice-president in charge of sales of the Baldwin Locomotive Works.

GEORGE K. MINERT, formerly assistant metallurgist, Gunite Foundries Corp., Rockford, Ill., is now metallurgist, Fort Pitt Malleable Iron Co., McKees Rocks, Pa.

CHARLES B. MARSHALL, JR., formerly a student engineer at National Tube Co., is now in the sales department of Babcock & Wilcox Tube Co., Welded Tube Division, Alliance, Ohio.

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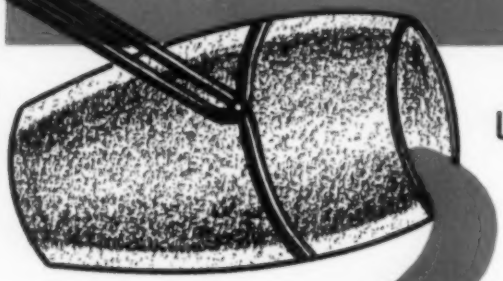

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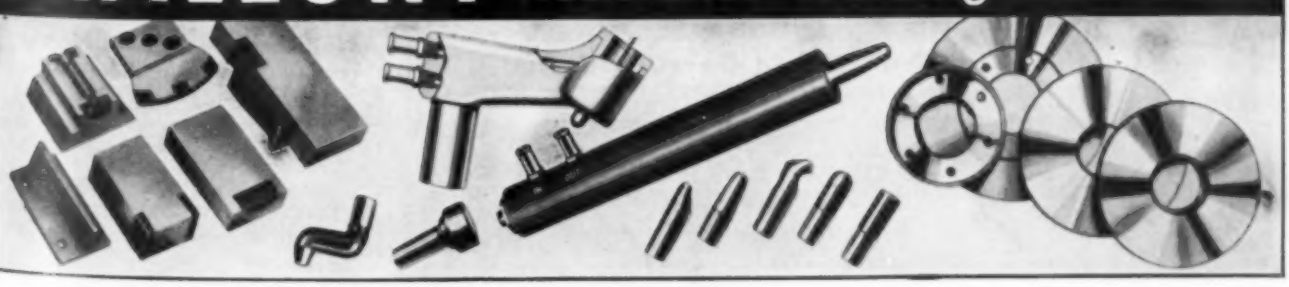

Electrolytic Films Protect Magnesium*

By N. Parkinson and J. W. Cuthbertson

MAGNESIUM is the most electropositive of the useful metals, and therefore it is hardly surprising to find that neither the metal nor the majority of the magnesium-rich alloys are particularly resistant towards corrosion. With few exceptions, the alloys intended for use in the open must be protected. Best results are obtained by a duplex process involving either a chemical or electrochemical pretreatment followed by spray painting.

A survey was made of the behavior of metallic magnesium in a variety of aqueous electrolytes. The protection of the two commercial alloys, rolled AM503 (2.0% Mn, 0.4% Si, 0.2% Zn) and cast A8 (8.5% Al, 0.5% Zn, 0.22% Mn, 0.12% Cu, 0.08 % Si) received co sideration, and a treatment involving an aqueous solution of chromi acid using either alternating cu rent or, on the other hand, direc current superimposed on alterna ing, was developed and studied. The degree of protection was est mated by *(a)* continuous immer sion, *(b)* intermittent immersion and *(c)* salt spray.

The painted specimens were prepared as follows: After pre filming, the samples were given full sprayed coat of a zinc chro mate pigmented primer; a week later a sprayed coat of gray cellu lose enamel was applied, followed by a second coat after a lapse o two days. The specimens then stood for two days before testing.

In no case was it found possible to build up thick films such as can be obtained by the anodization o aluminum; nor was any film com parable with the latter from the protective viewpoint. Apart from chromic acid, no other acid solu tion has been found capable o forming a coherent film on magne sium. Neither of the alloys studied responded favorably to direct cur rent electrolysis in chromic acid and attention was therefore con centrated on the action of alter nating current.

Two electrodes measuring 2x in. were cut from a thin sheet o the alloy. Duration of treatment was 30 min., the temperature and current density being maintained at 70° C. and 2.0 amperes per sq.dm. An increase in the tempera ture of the electrolyte or in current density darkened the color of the film. With the exception of those formed at temperatures exceeding 80° C., the darker films almost in variably proved to be more corro sion resistant.

Compared with films produced on aluminum by anodic oxidation those formed on magnesium by electrolysis (alternating current) are much thinner. It was thought that superposition of direct current would improve the process in this respect, and it was adjusted so that the mean value of the applied elec tromotive force was negative. When alloy AM503 was made cathodic, good films were produced, the best results being obtained at current densities of 2.0 to 3.0 amperes per sq.dm. for the alternating current and 0.5 to 0.75 *(Cont. on page 322)*

*(Abstracted from "The Surface Protection of Magnesium Alloys" *Journal*, Institute of Metals, Vol. 69, 1943, p. 109.)

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Bulletin 1023-2A Gives Details

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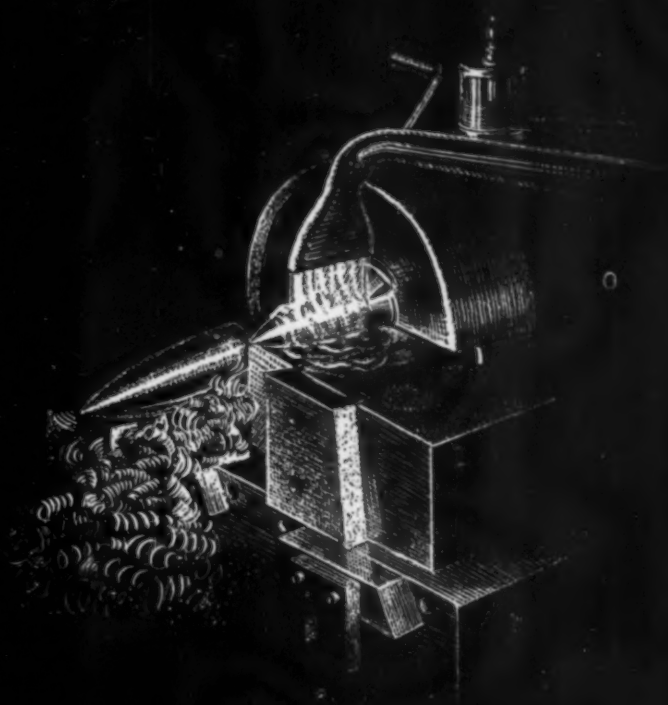

A manufacturer now turning out shell casings asked one of our Cities Service Lubrication Engineers to make a survey of his machining operations . . . Our Engineer recommended certain changes, including the use of a Cities Service Chillo Cutting Oil, which permits full visibility during the cutting operation. RESULTS: Tool life increased . . . cutting oil cost cut . . . production efficiency and quality of work both improved.

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and *Cities Service* means *<u>good</u> <u>service</u>*!

CITIES SERVICE OILS — ONCE-ALWAYS

CITIES SERVICE OIL COMPANY

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Mg Protection

(Cont. from page 320) for the direct. Superimposed direct current caused no discernible improvement in the treatment of cast A8, however.

Results therefore indicate that: *(a)* The wrought alloy AM503 can be effectively protected by treatment in hot, dilute chromic acid either with alternating current alone, or preferably with direct current superimposed, whereas cast A8 cannot be so protected; and *(b)* neither AM503 nor A8 can be protected by direct current electrolysis, irrespective of whether they are treated anodically or cathodically. Alloy AM503 solidifies in the ingot or sand casting to a homogeneous solid solution, but during rolling or forging while hot, a second constituent, said to be gamma-manganese, is precipitated. In cast A8, on the other hand, a degenerate eutectic crystallizes out, and the resulting structure consists of a solid solution plus the compound Mg_4Al_3. The heterogeneous distribution of the aluminum in this alloy is partly responsible.

When treated anodically, the alloys and metallic magnesium develop white films; conversely, under alternating current dark films are obtained tending to become black at high current densities and high solution temperatures. These films consist of one or more oxides or hydroxides, but their actual composition depends on the nature of the pre-treatment, and differs widely for the direct and the alternating current processes.

Chemical and spectrographic analysis of the dark colored films on AM503 revealed considerable quantities of manganese and chromium. It is believed that the black films obtained on A8 also owe their color to oxides of chromium.

Theoretical Aspect—The tendency to oxidize is greatest for aluminum and least for manganese. As regards AM503, the conditions of treatment favor the formation of MnO_2 and perhaps Mn_2O_3. The actual order of oxidation may be modified by secondary considerations. It is tentatively suggested that, for magnesium and its alloys, the increased solvent effect of the electrolyte accompanying the change from alternating to direct current is attributable to the colloidal nature of the newly formed MgO, which tends to be repelled from the electrode during the negative pulse.

It has been shown that the alloy AM503, but neither metallic magnesium nor the alloy A8, can be effectively protected against corrosion by alternating current treatment in hot 5% chromic acid. The excellent results obtained are attributable primarily to the low magnesium oxide content of the film which consists chiefly of a mixture of the oxides of chromium and manganese. Such films have a compact structure and when fully developed are able to suppress the oxidation of the magnesium and probably also of the manganese; their further growth is then largely due to deposition of oxides of chromium. The absence of these oxides in the films produced by direct current explains the failure of the anodic process to produce equally satisfactory results.

Compared with the most effective of the commercial dip chromating processes, the electrolytic process has the advantage of speed. It affords decidedly superior protection under the salt spray.

Make Control be the Center of Your Attention

on Combustion Equipment!

McKee Series "C" Valves should be applied on any control system where air flow is important.

Connect it to any control mechanism: pyrometer controller, thermostat, direct-acting thermostat valve, or steam pressure controller.

Minimum power consumption (only 8 watts) yet positive pneumatic action of many pounds of force!

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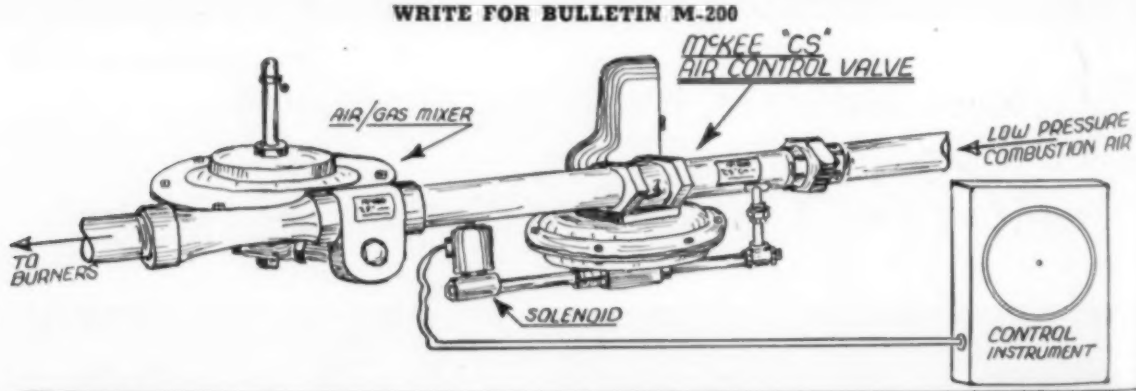

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Humid, rainy summer months are rust months and play havoc with metal production. Vital supplies of war materials are delayed—at times stopped.

Rust bottlenecks no longer need occur to hamper production. Peroline and Deoxidine will eradicate and prevent rust, making these stoppages or delays unnecessary either in rainy seasons or at other times.

Peroline (a combined chemical and oil) not only effectively retards corrosion on steel components in processing, in storage and in transit, but—it dissolves blushes of rust, eliminating the labor of a separate cleaning operation. There is a grade of Peroline for application to wet surfaces as well as grades for application to dry metal. Peroline is unique in its ability to clean and, when the oil phase is removed with degreasing solvents, to leave the surface properly conditioned for painting.

Surface Badly Rusted. If in processing, surfaces have become badly rusted, Deoxidine provides a fast and easy means for removing and eradicating rust and rust stimulators, leaving a surface properly prepared for painting.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

Powdered metal presses. Kux Machine Co. Bulletin 1.

Forging presses. Ajax Mfg. Co. Bulletin 2.

Horizontal extrusion presses. Hydropress, Inc. Bulletin 3.

36-page pictorial story of the Cecostamp. Chambersburg Engineering Co. Bulletin 4.

Cutting Oils. Cities Service Oil Co. Bulletin 5.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin 7.

Information and data on straightening press. Anderson Bros. Mfg. Co. Bulletin 10.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin 8.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin 21.

Catalog 44 is a new and enlarged reference to Kennametal tools and products. Graphically indexed, this 48-page catalog covers many metal working features. Kennametal, Inc. Bulletin 541.

Surface coated abrasive belts. Minnesota Mining & Mfg. Co. Bulletin 12.

Complete and valuable study of "Machining of Metals", including chip formation, is offered by National Refining Co. Bulletin 335.

Safe-T tongs and their use in materials handling are described in new booklet by Heppenstall Co. Bulletin 434.

63-page pocket booklet shows useful tables of weights and measures used in the metal industry. Mesta Machine Co. Bulletin 441.

Practical data sheet describes cutting and grinding compound. Diversey Corp. Bulletin 447.

8-page general catalog outlines the hard facing alloys and overlay metals of this company, with many illustrations and typical applications. Wall-Colmonoy Corp. Bulletin 484.

Attractive 16-page booklet describes the new "MX" grinding tools, citing many features and applications. Carborundum Co. Bulletin 518.

Struthers Wells Corporation's Tangent Bender and its ability to edge bend sheet metal in the lighter gauges is described in illustrated 8-page leaflet. Bulletin 520.

Air tools in steel mills and foundries are pictured in new booklet by Ingersoll-Rand. Bulletin 255.

This company has issued two new booklets showing new price lists for sintered carbides. Firth-Sterling Steel Co. Bulletin 486.

"Quality Control" is the title of this new 64-page pocket size handbook on scientific inspection. Continental Machines, Inc. Bulletin 479.

20-page booklet discusses typical problems involved in the selection and application of water-mix oils. D. A. Stuart Oil Co., Ltd. Bulletin 482.

Attractive new bulletin describes the Spencer Turbine Co.'s Sump-Vac, a new portable vacuum producer which is said to clean machine sump tanks in 2 to 10 min. Bulletin 494.

FERROUS METALS

Republic Steel Corp.'s second edition of National Emergency Steels tells you all about these new steels. Bulletin 345.

Page after page of useful technical data and reference tables on tool steels. Latrobe Electric Steel Co. Bulletin 367.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin 25.

Use Handy Coupon Below for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 350, 352, 354, 356, 358, 360, 364, 366, 368, 370, 374, 378, 380 and 384.

Metal Progress 7301 Euclid Ave., Cleveland 3, Ohio — August, 1944

Send me the Literature I have indicated below.

Name ..... Title .....

Company ..... Address .....

(Students—please write direct to manufacturers.)

Check or circle the numbers referring to literature described on these 15 pages.

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2	56	101	142	176	109	319	359	399	445	471	495	518	539
3	59	102	143	177	210	322	361	404	446	472	497	519	540
4	62	103	146	179	213	323	362	406	447	281	499	520	541
5	65	106	147	180	215	324	363	407	448	475	500	521	542
7	66	107	148	182	240	325	364	409	189	477	501	522	543
8	70	212	149	183	246	327	365	410	450	478	502	523	544
10	71	114	150	185	255	328	366	411	452	479	503	525	545
12	72	115	152	186	258	329	367	481	453	480	504	526	546
21	78	116	154	420	271	330	368	422	454	284	506	527	
25	79	117	155	190	439	331	369	424	455	482	507	528	
26	82	118	156	192	449	333	372	426	457	483	508	529	
30	85	119	158	193	288	335	374	428	458	484	509	530	
31	86	123	161	197	292	337	376	433	459	486	510	531	
33	89	128	162	199	296	338	380	434	461	487	511	532	
35	93	132	164	200	297	339	383	436	462	489	512	533	
40	94	134	167	201	301	343	384	437	463	490	513	534	
41	96	135	170	203	305	345	385	438	465	491	514	535	
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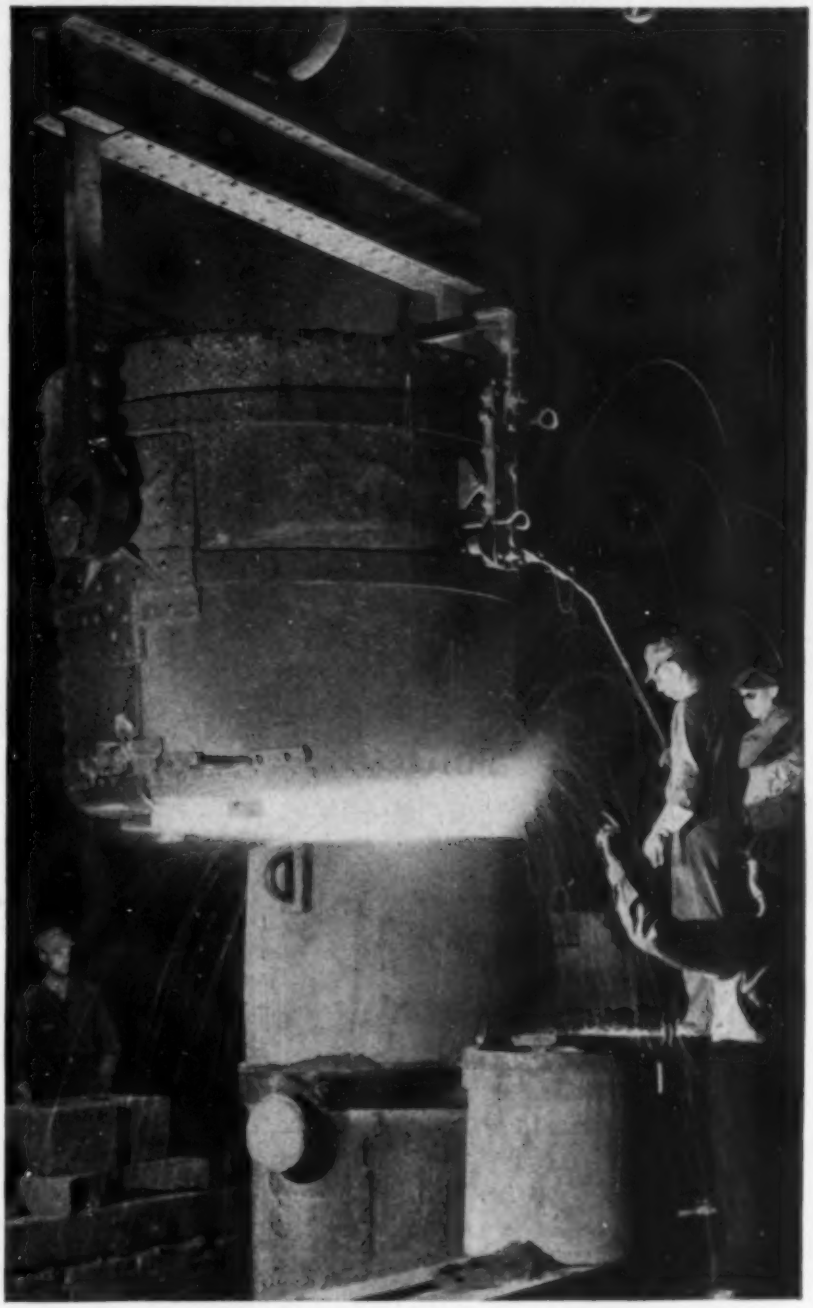
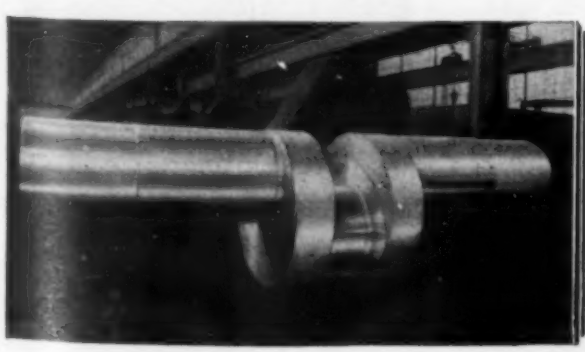
Made right, poured right and properly pre-heated, the steel ingot is ready for the expert forgesmithing, heat treating and high precision finish machining operations which are so essential in producing a forging that will deliver long sustained performance.

There is no divided responsibility when National Forge makes a forging and you always have greater confidence in the forgings that are National Forged.



A forging begins to take shape in the teeming of the ingot—a process simple to picture but highly important in the making of quality forgings.



For this extra heavy press crankshaft, an ingot of ample size was required to permit thorough working in the forging press—a National Forge practice which assures forgings of inherent stamina.

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Job-Designed
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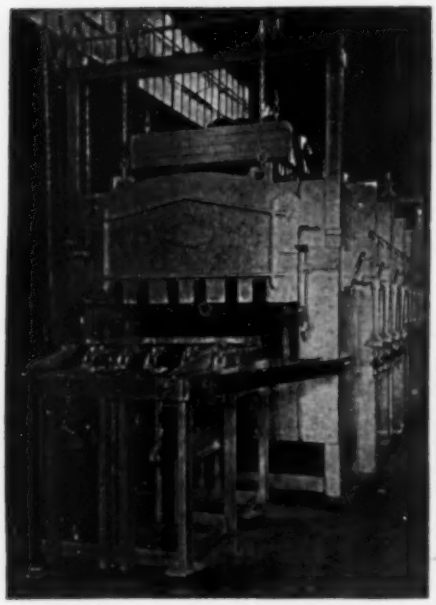

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

New 46-page booklet, "Wear, A Discussion of the Mechanism of Wear Phenomena and Influencing Factors", is said to be the first book in English on the subject of wear. Nitralloy Corp. Bulletin 539.

Molybdenum wrought steels. Molybdenum Corp. of America. Bulletin 26.

Free Machining Steels. Monarch Steel Co. Bulletin 30.

Chemical analyses, shapes and sizes of Joslyn stainless steel products. Joslyn Mfg. and Supply Co. Bulletin 297.

Tool Steels. Bethlehem Steel Co. Bulletin 31.

Enameling iron sheets. Inland Steel Co. Bulletin 33.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin 35.

Aircraft Alloy Steels. Joseph T. Ryerson & Son, Inc. Bulletin 40.

Attractive new catalog describes the line of steel offered by Peninsular Steel Co. Bulletin 337.

New Catalog C makes it easy to get International Nickel Co. literature, as it presents brief description and index to a wide variety of booklets. Bulletin 305.

"Graphitic Booklet" gives complete information on new, free-machining, long-wearing steel. Steel & Tube Div., Timken Roller Bearing Co. Bulletin 307.

HWD hot work die steel and Sterling stainless steels are described in four new leaflets by Firth-Sterling Steel Co. Bulletin 323.

Engineering and comparative information on porcelain enameled iron is presented in new illustrated booklet by American Rolling Mill Co. Bulletin 376.

New booklet gives full information on N-A-X high tensile and N-A-X 9100 Series of alloy steels. Great Lakes Steel Corp. Bulletin 328.

84-page tool and die steel handbook just issued by Ziv Steel & Wire Co. is a helpful guide to selection, treatment and use of these important steels. Bulletin 440.

Use Handy Coupon on Page 348 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 348, 352, 354, 356, 358, 360, 364, 366, 368, 370, 374, 378, 380 and 384.

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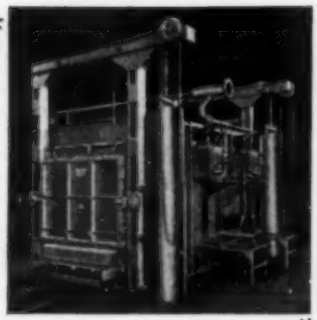

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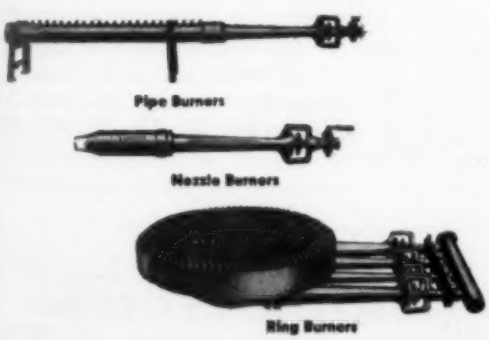

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Kinite alloy tool steel bar stock. H. Boker & Co., Inc. Bulletin 258.

Spindle speed calculator is handy chart to figure machining rates on bar steels. Bliss & Laughlin, Inc. Bulletin 333.

64-page booklet describes the welding of stainless steels. Allegheny Ludlum Steel Corp. Bulletin 384.

32-page booklet which pictorially and textually amounts to a scientific treatise on two carbon steels—Speed Case and Speed Treat—has been issued by W. J. Holliday & Co. Bulletin 450.

Fitzsimons Co. issues interesting leaflet on speed case and speed treat steels. Bulletin 452.

Molybdenum-Tungsten high speed steels marketed under the general trade name Mo-Max are discussed comprehensively in 52-page book by J. V. Emmons, metallurgist for the Cleveland Twist Drill Co. Bulletin 497.

Carpenter Steel Co. offers a convenient four-color chart useful in identifying various types of stainless steels which may have become mixed in stock. Bulletin 507.

Latest data chart, Section D, No. 1, shows government "specs" for alloy steels and corresponding commercial designations. Peter A. Frasse & Co., Inc. Bulletin 533.

NON-FERROUS METALS

80-page pipe and tube bending handbook has been issued by Copper & Brass Research Assn. Bulletin 399.

6th edition of Revere Weights and Data Handbook. Revere Copper and Brass, Inc. Bulletin 296.

This "Aluminum Imagineering Notebook" presents 12 important economic advantages of aluminum and illustrates numerous examples of things which have been imagineered into aluminum actualities. Aluminum Co. of America. Bulletin 472.

Copper Alloys. American Brass Co. Bulletin 45.

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin 41.

Die casting equipment. Lester-Phoenix, Inc. Bulletin 42.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin 56.

"Designing with Magnesium" is title of new book offered by American Magnesium Corp. Bulletin 433.

Two new Ampco Metal data sheets discuss forging Ampco to improve physical characteristics and use of Ampco for non-scratching feed fingers. Bulletin 314.

Printed information on Lithium of interest to nonferrous and physical metallurgists is available from Lithaloys Corp. Bulletin 532.

Two new bulletins present many interesting facts on aluminum tubing and aluminum wire, rod and bar. Reynolds Metals Co. Bulletin 540.

"Some Considerations in Making Test Bars" is the title of an interesting booklet by Federated Metals Div., American Smelting and Refining Co. Bulletin 529.

Red-X Aluminum Alloys, produced by the largest single producer of Commercial Aluminum and Magnesium Alloys, the National Smelting Co., are described, applications studied, in this 16-page file folder. Bulletin 499.

Dowmetal data book. Dow Chemical Co. Bulletin 51.

Facts on Beryllium Copper, including composition, forms available, applications and extensive additional information are presented in this new 16-page booklet by the Riverside Metal Co. Bulletin 511.

WELDING

"Things To Know About Welding Stainless Steel" is title of new booklet that answers many welding questions. The McKay Co. Bulletin 544.

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin 59.

40-page catalog reviews the progress and many applications of low temperature welding. Eutectic Welding Alloys Co. Bulletin 471.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin 62.

Welding and brazing of aluminum, a new data book issued by Aluminum Co. of America. Bulletin 66.

Data book facts on spot, seam and flash welding ferrous and non-ferrous metals and alloys. P. R. Mallory & Co., Inc. Bulletin 65.

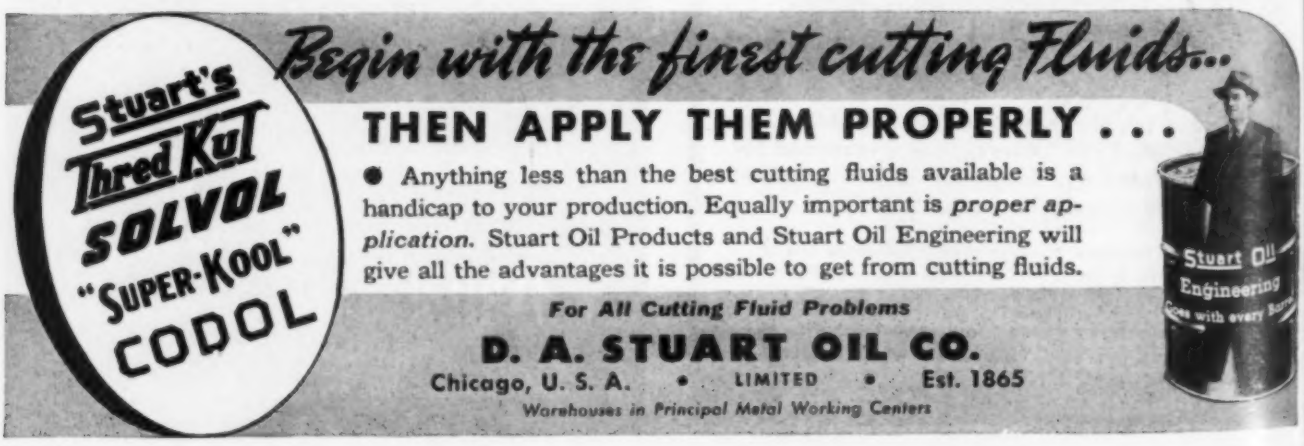
Nu-Braze No. 4, an improved silver brazing alloy. Sherman & Co. Bulletin 288.

Two new hard-facing alloys furnished as welding rods for application by Oxy-Acetylene process are described by the Stoody Co. in Bulletin 325.

Arc welding inspection chart, designed so that operators can tell at a glance whether welds are being properly made, has been issued by the Lincoln Electric Co. Bulletin 411.

Use Handy Coupon on Page 348 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 348, 350, 354, 356, 358, 360, 364, 366, 368, 370, 374, 378, 380 and 384.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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Comparable arc welding electrodes for stainless are shown in chart issued by Alloy Rods Co. Bulletin 353.

Helpful electrode color chart is offered by the Arcos Corp. Bulletin 374.

New Phos-Copper booklet explains ways to braze, design and applications. Westinghouse. Bulletin 455.

16-page booklet describes welding and cutting equipment. Victor Equipment Co. Bulletin 489.

32-page booklet presents numerous experience reports from large users of arc welding. General Electric Co. Bulletin 513.

Air Reduction Sales Co. offers 20-page revised price list, "Gas and Electric Welding Supplies and Accessories". Bulletin 512.

Bulletin No. 14, "How To Repair Broken Cutting Tools With Easy-Flo", is filled with practical, instructional copy, profusely illustrated. Handy & Harman. Bulletin 506.

Pocket-sized, slide-type guide showing proper tip sizes, gas pressures, and other data required for machine gas-cutting steel is offered by Air Reduction. Bulletin 527.

TESTING & INSPECTION

New Burrell Shaker for general laboratory use is described in new catalog issued by Burrell Technical Supply Co. Bulletin 543.

Latest technical literature on x-ray and radium protection, together with lead products catalog, has been issued by Bar-Ray Products, Inc. Bulletin 463.

The Bristol-Rockwell dilatometer and its use is described in this leaflet by The Bristol Co. Bulletin 465.

Metallurgical polishing equipment offered by Precision Scientific Corp. is described in illustrated booklet. Bulletin 359.

Various methods and specifi plications of the measurement depth are described in illus pamphlet offered by Allen B. D Laboratories, Inc. Bulletin 33

Bibliography of more tha papers dealing with the p graphic method of metal analy a booklet discussing this equi is offered by E. H. Sargent Bulletin 338.

SR-4 strain gage and illustr of its many uses. Baldwin wark. Bulletin 70.

New book contains wealth o tical, usable information on trial inspection by x-ray. We house Electric & Mfg. Co. Bullet

Universal testing machine typical uses. Riehle Testing M Div., American Machine and Inc. Bulletin 86.

X-Ray Diffraction Unit. G Electric X-ray Corp. Bulletin

Inspection of non-magnetic with the new Zyglo method. M flux Corp. Bulletin 78.

Industrial radiography wit dium. Canadian Radium & Ur Corp. Bulletin 79.

Portable Brinell hardness test folding Brinell microscope. A King. Bulletin 85.

Optical Aids. Bausch & Lom tical Co. Bulletin 94.

Metallographic polishing p Conrad Wolff. Bulletin 96.

Metallurgical Equipment. A I. Buehler. Bulletin 97.

"Radiography of Materials" i of new 96-page book on indu radiography. Eastman Kodak Bulletin 331.

Stresscoat, a method of anal distribution, direction and va local strains. Magnaflux Bulletin 301.

Hardness testing equipment. son Mechanical Instrument Co. Bulletin 98.

Attractive, illustrated booklet scribes Clark Instrument's pre hardness tester. Bulletin 318.

High intensity industrial i nator is illustrated and describ new leaflet by Kelley-Koett Mfg Bulletin 406.

30th Anniversary Catalog s the special metallurgical equip offered by Claud S. Gordon Co. letin 410.

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Other Manufacturers' Literature L on Pages 348, 350, 352, 356, 358, 36 366, 368, 370, 374, 378, 380 and 384

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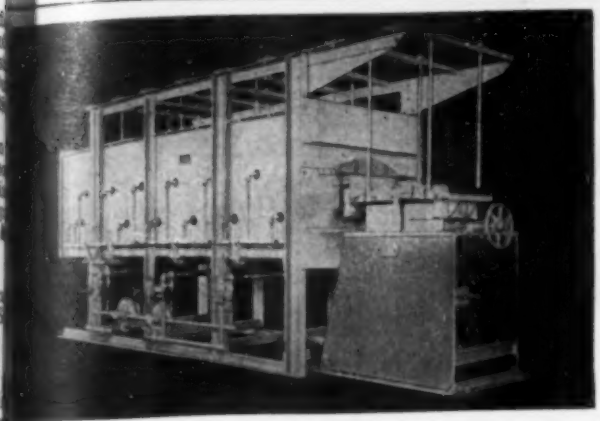

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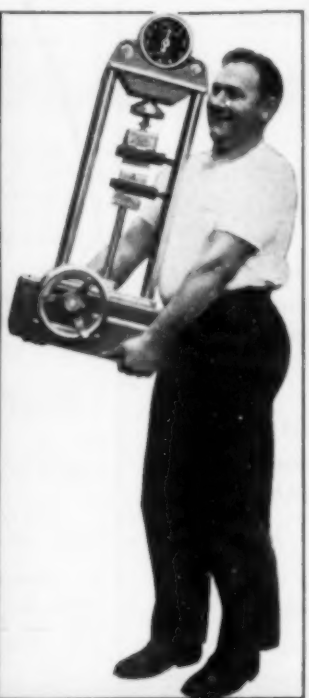

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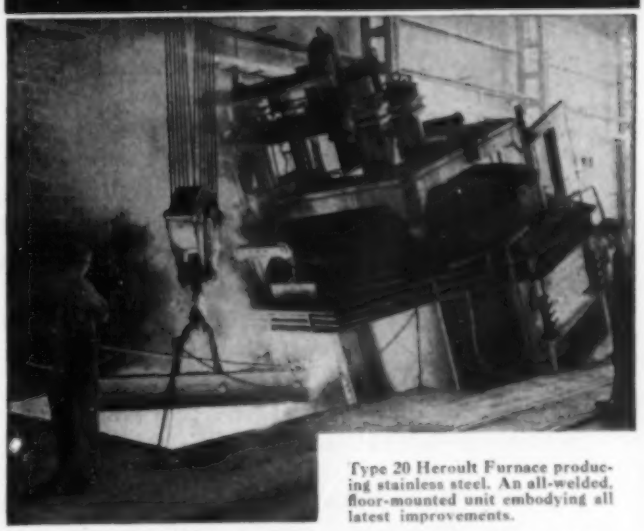

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WHAT'S NEW

IN MANUFACTURERS' LITERATU

Laboratory and industrial pH m ters are described and explained leaflet issued by Beckman Instr ments Division. Bulletin 422.

Details and various applications the portable tensile tester are show in 8-page leaflet by W. C. Dillon Co., Inc. Bulletin 491.

Advantages and speed of testi with the Magnetic Analysis Corp. Comparator are described and pi tured in brochure just released. Bu letin 492.

8-page illustrated leaflet describe line of industrial instruments o fered by the Brush Development C Bulletin 428.

6-page leaflet describes the co stant temperature equipment offere by American Instrument Co. Bu letin 493.

New Carbon and Sulphur Dete minator is described in this ne 8-page leaflet. Harry W. Dietert C Bulletin 501.

Many tips and suggestions fo industrial laboratories are presente in 24-page March issue of "Curve and References" by Wilkens-Ande son Co. Bulletin 502.

4-page folder on the inspectio and control of surface finish offered by George Scherr Co. Bu letin 508.

New Norelco electronic Searchra Modal 150 is described and sever features illustrated in this 4-pag leaflet. North American Philips C Inc. Bulletin 517.

New 50 KV industrial x-ray un ts features and applications, a presented in this 8-page leafle Picker X-Ray Corp. Bulletin 525.

TEMPERATURE CONTROL

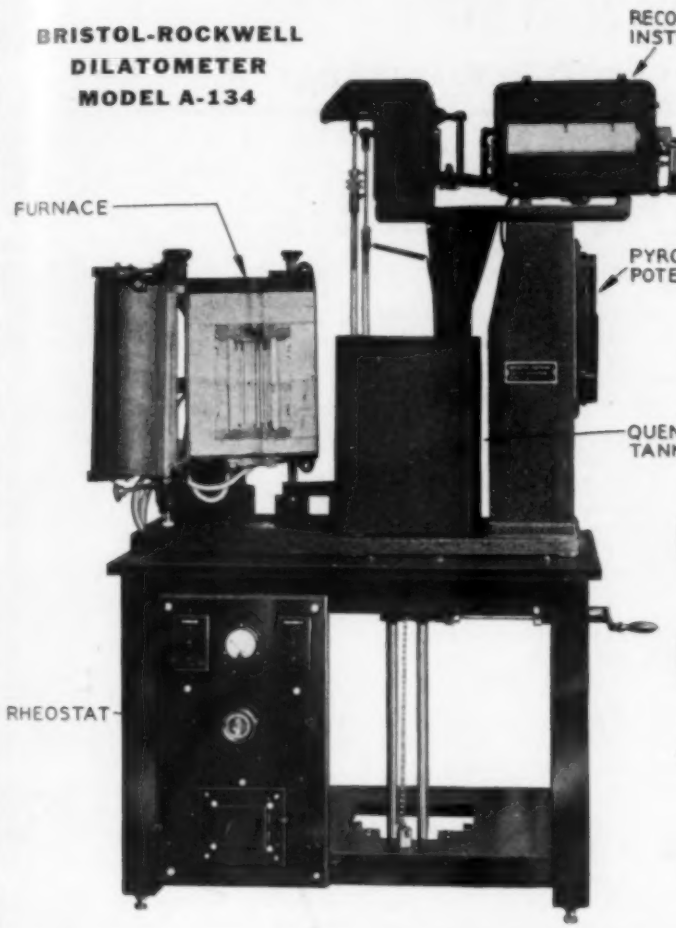
Potentiometer temperature indic tors. Foxboro Co. Bulletin 82.

Micro-Optical Pyrometers. Pyrom eter Instrument Co. Bulletin 89.

Pyrometer control of high spee salt baths is described in new book let by Brown Instrument Co. Bulle tin 324.

Industrial thermocouples. Arkl S. Richards Co. Bulletin 93.

Use Handy Coupon on Page 348 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 348, 350, 352, 354, 358, 360, 36 366, 368, 370, 374, 378, 380 and 384.



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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Operating principle and types available of the synchronous-motor-driven cam program timer are covered in this new 4-page folder. Automatic Temperature Control Co., Inc. Bulletin 487.

36-page thermocouple data book and catalog describes products, prices and presents recommendations for thermocouple users. Wheelco Instruments Co. Bulletin 490.

The Bristol Co. announces a new bulletin B220 describing its new line of Free-Vane Electronic Controllers for temperature, pressure, liquid level and humidity. Bulletin 503.

48-page revised catalog, "Micromax and Speedomax Rayotube Pyrometers", pictures applications of this equipment to important new temperature-measuring jobs. Leeds & Northrup Co. Bulletin 514.

Many types of pyrometers and temperature controllers are illustrated in this 4-page leaflet by Illinois Testing Laboratories, Inc. Bulletin 519.

HEATING • HEAT TREATMENT

Attractive 4-page leaflet describes uses, construction features and design of electric car bottom furnaces. Hevi Duty Electric Co. Bulletin 537.

McKee "Walltite Proportioning" and "Entrainment" gas burners are described in new bulletin by Eclipse Fuel Engineering Co. Bulletin 538.

Convection tempering furnaces with temperatures up to 1300 deg. F. are described in this new Hevi Duty Electric Co. Bulletin 542.

"Isothermal Quench Baths Applied to Commercial Practice" is the title of this 12-page paper, a practical and useful discussion of S curves in heat treatment. Ajax Electric Co., Inc. Bulletin 461.

32-page booklet describes 16 interesting industrial uses of high frequency electrical induction. Ohio Crankshaft Co. Bulletin 459.

Quenching oil coolers in heat treating practices are described in this leaflet by the Sims Co. Bulletin 462.

New catalog No. 406 describes Rockwell valves for control of air, gas and liquids. W. S. Rockwell Co. Bulletin 466.

24-page technical data and operating manual covering the Deepfreeze low temperature industrial chilling machines has been issued by Deepfreeze Div., Motor Products Corp. Bulletin 398.

Neutral baths for heat treatme and details of their use are describe in this booklet by the A. F. Holde Co. Bulletin 469.

36-page catalog illustrates Kol Hold line of thermal, sub-zero an stratosphere processing and testin machines. Kold-Hold Mfg. Co. Bulle tin 99.

Induction heating. Induction Hea ing Corp. Bulletin 103.

Internally heated salt bath furnace and pots. Upton Electric Furnac Div. Bulletin 102.

8-page pictorial bulletin describe the heat treating service of Conti nental Industrial Engineers, Inc. Bul letin 107.

Lithco, the chemically-neutral hea treating process, and Lithcarb, th process for fast, bright gas-carburi ing. Lithium Corp. Bulletin 101.

Furnaces for heat treatment of alu minum, magnesium and their alloys Lindberg Engineering Co. Bulleti 271.

Electric Furnaces. Ajax Electro thermic Corp. Bulletin 106.

Gas, oil, and electric heat treatin and carburizing furnaces. Holcro & Co. Bulletin 114.

Industrial furnaces, equipment fo bright annealing stainless steels an ammonia dissociation equipment Drever Co. Bulletin 115.

Industrial ovens, rod bakers, weld ing rod ovens, furnaces. Carl-Maye Corp. Bulletin 116.

Full muffle and other heat treatin furnaces described in catalog b Charles A. Hones, Inc. Bulletin 11

Non-metallic Electric Heating El ments. Globar Div., Carborundu Co. Bulletin 119.

56-page vest pocket data book o heat treating practices and proce dures. Chicago Flexible Shaft Co. Bulletin 118.

Molten Salt Baths. E. I. duPont deNemours & Co., Inc., Electrochemicals Department. Bulletin 123.

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Other Manufacturers' Literature Listed on Pages 348, 350, 352, 354, 356, 360, 364, 366, 368, 370, 374, 378, 380 and 384.

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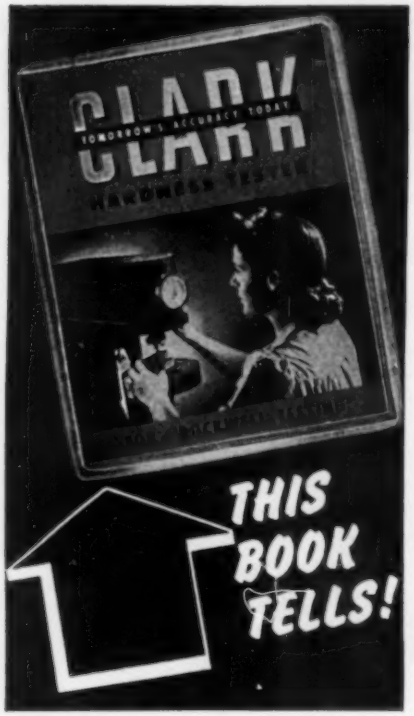

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WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Handling cylinder anhydrous ammonia for metal treaters. Armour Ammonia Works. Bulletin 128.

Certain Curtain Furnaces. C. I. Hayes, Inc. Bulletin 134.

Air-Oil Ratiotrol for proportioning flow of fuel oil and air to oil burners. North American Mfg. Co. Bulletin 135.

Two new bulletins on vertical carburizers and on carbonia finish. American Gas Furnace Co. Bulletin 139.

Controlled atmosphere furnace. Delaware Tool Steel Corp. Bulletin 141.

Dual-Action quenching oil. Gulf Oil Co. Bulletin 132.

Furnaces. Tate-Jones Co. Bulletin 142.

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin 143.

Vertical Furnace. Sentry Co. Bulletin 148.

Heat treating, brazing and melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin 147.

Conveyor Furnaces. Electric Furnace Co. Bulletin 149.

High and low temperature direct fired furnaces. R-S Products Corp. Bulletin 146.

New Electric Furnace. American Electric Furnace Co. Bulletin 150.

Electric Furnaces for laboratory and production heat treatment. Hoskins Mfg. Co. Bulletin 152.

"The Lectrodryer in the metallurgical industries," a new 4-page bulletin by Pittsburgh Lectrodryer Corp. Bulletin 155.

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin 161.

Flame-type mouth and taper annealing machine for steel cartridge cases. Morrison Engineering Corp. Bulletin 154.

Use Handy Coupon on Page 348 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 348, 350, 352, 354, 356, 358, 364, 366, 368, 370, 374, 378, 380 and 384.

ZIV'S NEW Carbide Tipped TOOLS

This new carbide tip, a speci product backed by Ziv's 33 yea of experience, assures great economy and higher productio in your tooling operations. Ava able in standard shapes. Speci shapes on request. Four grad of Ziv's carbide tips to selec Come ready for use.

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Delloy Cutting Tools *hold their edge* longer. Use them . . . for all turning, boring, planing and facing operations, for *proof* that their longer cutting-life means fewer grinds and less down time. No matter what your cutting needs, you'll find that a Delloy tool, bit or tip will do the job *better* and faster.

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Complete metallurgical and laboratory control assure absolutely uniform standards of density and hardness, in all grades of Delloy Tools.

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Q-ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION X-ite

John J. Tansey
New G. A. Vice President

JOHN J. TANSEY, formerly Assistant Treasurer of General Alloys, who came with the company in 1926 when he was 18 years of age, and learned the business from the ground up — starting in the Pattern Department and working through the organization — was elected Vice President of General Alloys effective July 1st. He studied accountancy, qualified for C.P.A., and studied extensively. He has become expert in tax law and government regulations, meanwhile juggling foundry yield ratios, cajoling absentees and sparring with Bureaucrats.

NO man has worked harder to build General Alloys Company. Despite his flair for economics and their routine application, known as "economies", John unhesitatingly ordered processes and practices which greatly increased our costs to maintain G.A. quality with W.P.B. ordered sub-standard materials.

GENERAL Alloys has had many success stories of young men who have grown up in the organization, many are still with us, some "outgrew" us, or vice versa. John Tansey has stood out by his modest, quiet achievement. John has mastered many difficult problems, in good times and bad, by which he contributed to General Alloys' success. For his loyal, untiring work and wise counsel, all of us in General Alloys are indebted—none more than the writer. Sure, H.H.H. needs a "balance wheel" — meet the "B.W." — J. J. Tansey.

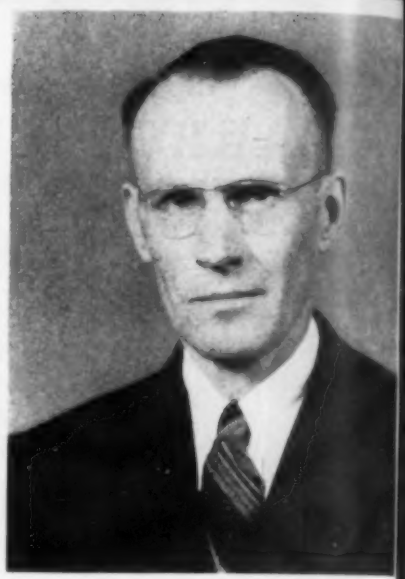
Ed Donnellan — Nee A.S.M. Now General Alloys Vice President Says "Thanks"

MANY of my good friends in the A.S.M. have written, phoned or told me that they were much surprised that I had pulled anchor (now that I am living in a seaport I am trying to learn nautical terms) with the greatest Metallurgical Society in the world. Perhaps I even surprised myself, but my change in position has been made possible because of you A.S.M. members.

IN my position in the A.S.M. I was sitting at the crossroads of the greatest Metallurgical Clearing House in the world. For over 20 years I sat around committee tables or contacted you A.S.M. members who were doing big things metallurgically. I not only enjoyed learning of your trials and tribulations and great industrial accomplishments, but from you I gained remarkable insight into metallurgical processes and operations.

MANY times as I listened to your experiences I had a desire to be more a part of the industrial program that you were all so nobly contributing to. At those A.S.M. Committee Meetings there was much real talk that encouraged me to again enter industry. During the meetings there were moments of philosophizing when some real gems were born such as the time Harry McQuaid spurred a committee to higher metallurgical accomplishments by this choice remark: "The greatest hindrance to progress is the satisfied mind." Such friends and contacts in the A.S.M. created a desire within me to take on more responsibility and I realize those meetings and discussions have contributed greatly to my metallurgical training and progress. For this I thank all my good A.S.M. friends.

IN the A.S.M. I was, of course, closer to Bill Eisenman who is still super-tops with me and a real true friend. It was under Bill's guidance that I acquired my business training and instructions for conducting the Society's activities that I was responsible for. I could not have had a better instructor and leader for that



J. Edward "Ed" Donnellan

work. With great pleasure to me, Bill has asked me to continue for the time being to act as technical committee secretary and next fall to help in the operation of the Metals Show. These things, and many others, I am glad to do, and always will be, for Bill Eisenman and the A.S.M. It is also wonderful for me and, I hope, to the A.S.M., that Mr. H. H. Harris, President of General Alloys Company has so willingly granted me the time for this Society activity.

WHILE on the sidelines I observed many metallurgical developments and applications. All were interesting, but what fascinated me most was the potential possibilities in the proper engineering design and application of high temperature alloys. In watching alloy mechanisms, it was quite evident to an observer on the sidelines that some alloys were just puddled together whereas others were monuments of intelligent engineering and manufacturing processes. This was forcefully illustrated recently while discussing alloy problems with Ed. Whiteside, District Manager (General Alloys Company, Cleveland). He showed me results obtained by such firms as Chase Brass and Cleveland Tractor where Q-Alloy castings have been in service as furnace parts for 12, 13 and 15 years. Many other similar examples have been presented to me, but I am definitely convinced that my new Company (General Alloys Company) is old in experience and really knows how to put years of service in furnace parts. In fact, for high temperature work the parts must be of Q-Alloy for real controlled durability. In my travels and future contacts I hope I shall have the opportunity of helping my A.S.M. friends with their high temperature problems.

AT this time I want to thank every A.S.M. member who contributed so greatly to my work in the A.S.M. and made that work on the Handbook and the Show so interesting and enjoyable.

J E Donnellan

"HEATRAP" DOOR 3 ft. high x 22 ft. long, made of practically indestructible SPIRALINK, is door for giant pipe annealing furnace.

E FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

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A GENTLEMAN, AN ENGINEER, A PURCHASING AGENT

LOUIS TEKER, Purchasing Agent of Leeds & Northrup, slept,—never to awaken,—on the night of June eleventh. Fatigued from long and selfless exertion, his loyal heart was overtaxed.

HE had carried through a procurement program of the utmost complexity with the precision of an L&N instrument.

LOUIS TEKER'S contribution toward Allied Victory rode the waves of invasion, struck with the bombs upon Berlin, sped swiftly underseas. Literally, that is true, for as American Metallurgy has tooled Victory, so has L&N instrumented American Metallurgy.

SURELY no men contributed more to the might and worth of Allied Arms than those engineers of Procurement who sought, sorted and assembled for battle the steel sinews of war. And as surely Louis Teker stood among his contemporaries as his company stands in World Technology and American Industry.

Louis Teker's philosophy of justice and equity, and his loyalty to principles, persons and ideals was not of himself alone. He strove beneath a mask of genial dignity with every fibre of his mind and being to live up to the high responsibility attending his great privilege as face and hand of Leeds & Northrup in his dealings with "suppliers"; "loyal coworkers" would describe them better.

WE know Leeds & Northrup from working with them, with ardour and loyalty to reciprocate their confidence through the years. We understand the dynamic integrity which motivates their search for truth and perfection in research—in men, and in materials. This, and much more, is inherent in Leeds & Northrup policy and products.

INSPIRED and projected by the Company's founders, Leeds & Northrup policy has been enhanced, has gained stature through the lives and work of many men who have projected and perfected it through practice. One such man was Louis Teker. He, in his dealings, was always the Company.

VISITING with us a few days before his passing, Lou had authorized new patterns of utmost quality, some even in stainless steel, costing thousands more than ordinary patterns would have cost. He was investing in L&N quality, in accuracy, and in delivery, laying the *foundation first*. "Mr. Teker", said our Superintendent, "No one has ever worked with us to make the best possible castings as you have." "Well", replied Lou, "That's our *Policy*, on November 3rd, I will have been thirty-five years with L&N, we have never compromised with quality." In his eyes shone his greatest pride, that of the Company he was so proud to represent, to possibly the most select group of suppliers in U.S.A.

LOUIS TEKER
Late Purchasing Agent of Leeds & Northrup Co.

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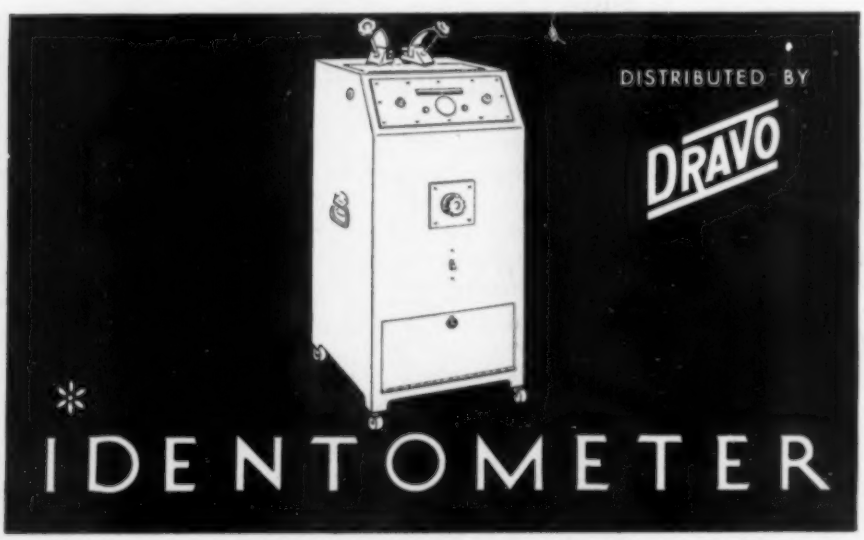
this girl is identifying STEEL *positively*

With only a few hours training in the operation of the Identometer, this girl can, through the use of known samples of most rolled or forged ferrous alloys, determine if unknown pieces are: (1) of the same or different chemical composition, if the physical structure is the same; (2) of the same heat or different heat treatments, if the chemical composition is the same.

One manufacturer reports 4,000 bars of steel tested and separated into 68 different heats in three weeks time and without delaying production!

The instrument is the Identometer. Its principle: thermo-electricity. It's portable, accurate, and fast. For a full "how it works" description, send now for Bulletin 115. DRAVO CORPORATION, *National Department*, 300 PENN AVENUE, PITTSBURGH 22, PA.



AN ELECTRICAL INSTRUMENT FOR THE INSTANT AND ACCURATE IDENTIFICATION OF MOST ROLLED OR FORGED FERROUS ALLOYS BY THE USE OF REFERENCE SPECIMENS

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Turbo-Compressor data book shows how to calculate compressed air systems for a dozen different applications. Spencer Turbine Co. Bulletin 329.

High Temperature Fans. Michiana Products Corp. Bulletin 158.

No-Carb, a liquid paint for prevention of carburization or decarburization. Park Chemical Co. Bulletin 156.

Catalog of heat treating materials. Heatbath Corp. Bulletin 322.

Standardized sizes of semi-muffle and pot-type furnaces are described and pictured in new leaflet by Dempsey Industrial Furnace Corp. Bulletin 354.

Use of pulverized coal in the metallurgical industries, equipment and designs, are described by Amsler-Morton Co. in Bulletin 361.

Rapid oil coolers and heat transfer equipment are described in new catalog issued by Bell & Gossett Co. Bulletin 365.

Laboratory and tool room furnace. Mahr Mfg. Co. in new Bulletin 327.

82-page catalog describes in detail General Electric heat treat furnaces. Bulletin 380.

Furnaces for heat treating tools, dies and parts are described in new leaflet by Despatch Oven Co. Bulletin 362.

New booklet describes uniform case hardening up to .150" with controlled carburizing baths. American Cyanamid & Chemical Corp. Bulletin 372.

New book "Hardness" describes and evaluates hardness research of noted pioneers, methods of testing and testing instruments. Nitralloy Corp. Bulletin 366.

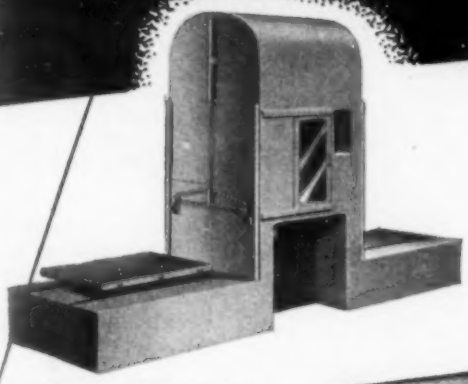
Four basic heat treating atmospheres are described in new booklet by Westinghouse. Bulletin 383.

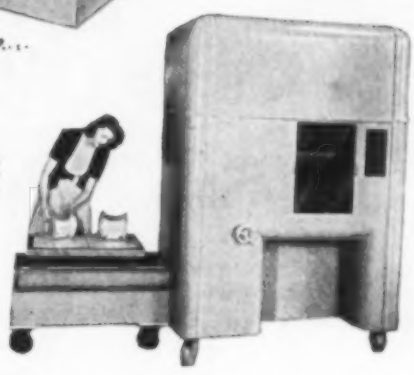
The complete line of heat treating furnaces, burners and other equipment of this company is described and illustrated in new bulletin "D" just issued. Eclipse Fuel Engineering Co. Bulletin 483.

Use Handy Coupon on Page 348 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 348, 350, 352, 354, 356, 358, 360, 366, 368, 370, 374, 378, 380 and 384.

KELEKET X-RAY CAN IMPROVE YOUR PRODUCT

KELEKET *radiographic cabinet used for inspecting critical airplane parts.*





KELEKET's *mobile inspection cabinet operates fluoroscopically or radiographically.*

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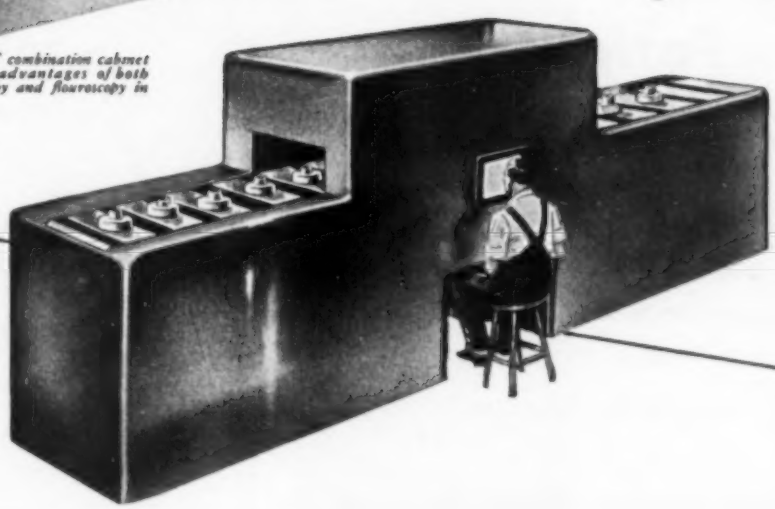

KELEKET's *conveyor belt fluoroscopic cabinet for high-speed, continuous inspection, may also be used radiographically.*

There is no question about X-ray's performance in industry today—nor the job it can do on the product you make.

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KELEKET—the quality name in X-ray—knows industrial inspection through and through. KELEKET knows above all that X-ray equipment must fit your plant. That's why KELEKET incorporates X-ray into cabinets—fluoroscopic, radiographic, or a combination of both—if that's what your production set-up requires. That's why KELEKET cabinets are stationary or mobile—or even conveyor units that become an integral part of a moving assembly line.

Hundreds of KELEKET installations in plants all over the country are improving products, cutting costs, and preventing failures in use. Tell us your problem, show us your plant, and we'll demonstrate how X-ray can serve you best.

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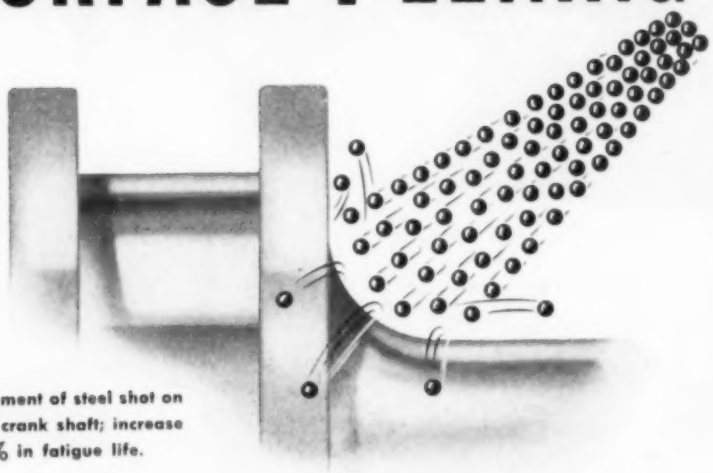
SURFACE PEENING



Impingement of steel shot on fillet of crank shaft; increase of 900% in fatigue life.

Increases Fatigue Life of Metals 300% to 1500%

● Somewhat like sandblasting, peening is *shot-blasting* —thousands of metal balls (steel shot) hurled against the surface of the metal part, with proper control of direction, velocity, size of shot, time of exposure, etc.

Large parts are peened individually; small parts may be mass peened.

Surface-peening generally increases fatigue life several hundred per cent. Numerous examples prove this. It is being used extensively in several fields, notably automotive and aeronautical—and is spreading rapidly.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

"Heat Treating Topics" is title of new bulletin of special interest to heat treaters, issued by Rex & Erb. Bulletin 424.

Vapocarb-Hump method for heat treatment of steel is the title of a newly-revised catalog issued by Leeds & Northrup. Bulletin 453.

Thirty-two-page booklet, "Production Data," presents several articles from "The Houghton Line." E. F. Houghton & Co. Bulletin 475.

112 pages packed solid with down-to-earth data on industrial combustion and heat practice. Hauck Mfg. Co. Bulletin 477.

A new technical bulletin gives information on Calliflex Bi-metal. Callite Tungsten Corp. Bulletin 478.

Aero Heat Exchangers for the constant and accurate control of temperature in liquids or gases are described in this 4-page leaflet by Niagara Blower Co. Bulletin 516.

Heat treatment of steel wire and furnaces used are discussed in this leaflet by Surface Combustion. Bulletin 523.

Gas-fired tool room furnaces and pot furnaces are described in these two booklets by Bellevue Industrial Furnace Co. Bulletin 522.

Interesting 20-page booklet contains extensive heat treating information, including a glossary of terms, table of weights of square and round bars and a hardness conversion table. Pittsburgh Commercial Heat Treating Co. Bulletin 509.

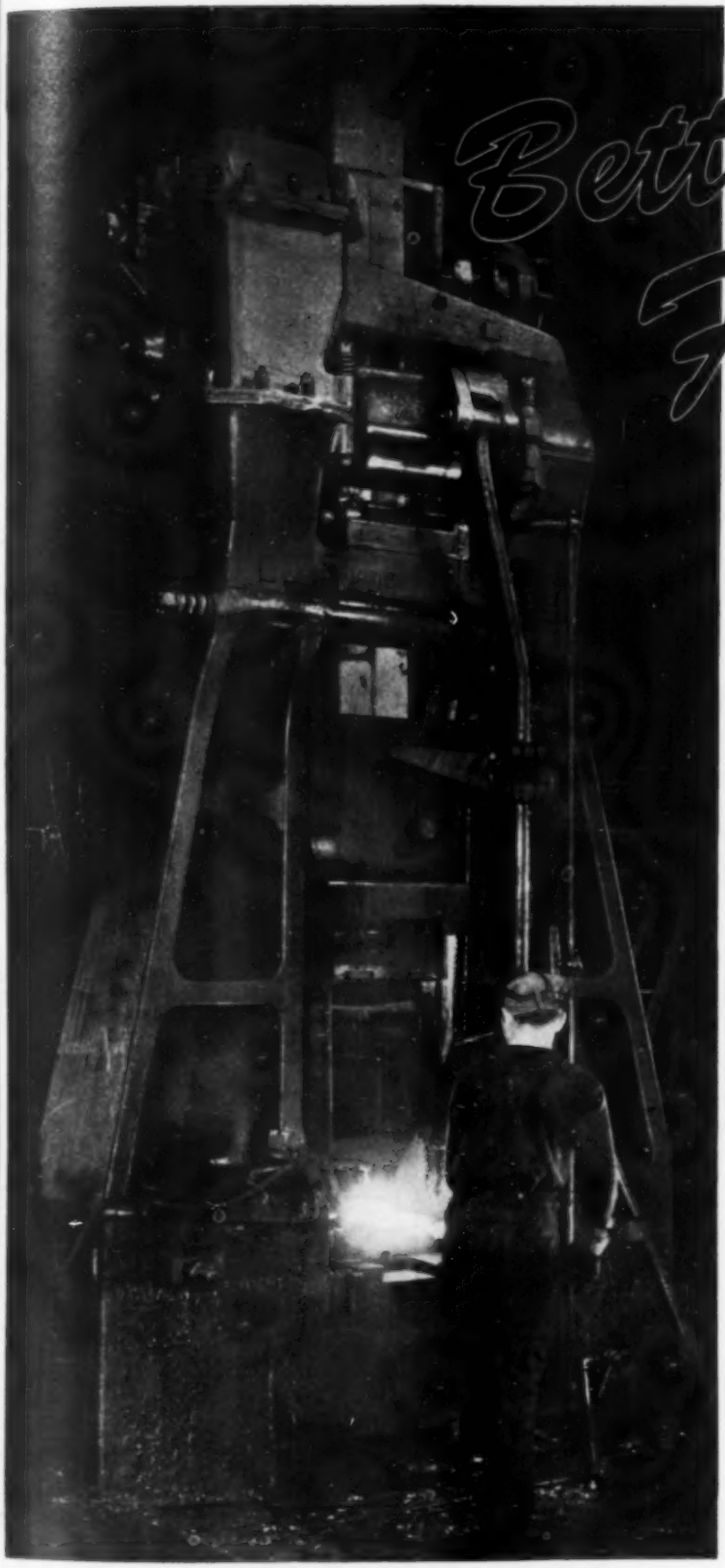
Merits and economy of pulverized-coal firing for metallurgical furnaces are discussed in this bulletin by Babcock & Wilcox Co. Bulletin 530.

REFRACTORIES & INSULATION

Electric-furnace graphite molds and sintering boats and carbon heat treating boxes are described in Catalog Section M-8000. National Carbon Co. Bulletin 545.

Insulating firebrick. Babcock & Wilcox Co. Bulletin 162.

Use Handy Coupon on Page 348 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 348, 350, 352, 354, 356, 358, 360, 364, 368, 370, 374, 378, 380 and 384.



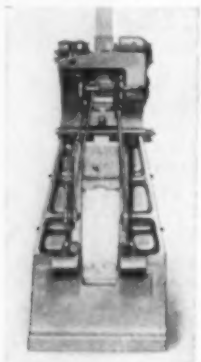
Better Drop Forgings

from Model J-2 CHAMBERSBURG Board Drop Hammer

In these war years when metal parts have been tested in the destructive jaws of the war machine and either discarded or ordered in increasing numbers, drop forgings have proved once again their essential value.

And for those drop forgings that can be made on the board drop hammer, the Chambersburg Model J-2 Hammer offers a greater degree of precision forging over a longer period of time.

Forgings made on this efficient hammer can be made to closer tolerances, are more uniform in quality and can be produced in greater quantities per hour.



Rear of Hammer showing Simplicity of Design.

The motor driven head is the acme of simplicity and quietness. The clean, well-proportioned lines of the hammer as shown in the illustration are indicative of the heavy, well-balanced anvil and frames.

Further details are described in Bulletin 252-2. Write for a copy.

CHAMBERSBURG ENGINEERING CO., CHAMBERSBURG, PA.

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This policy resulted in an enviable record of "long-time" customer relationship. In the period immediately preceding the war 80 per cent of all Pangborn business was repeat business.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Heavy Duty Refractories. Norton Co. Bulletin 164.

Conductivity and heat transfer charts. Johns-Manville. Bulletin 167.

D-E insulating materials and their application are described in new data booklet by Armstrong Cork Co. Bulletin 208.

Zircon refractories in aluminum open hearth furnaces. Chas. Taylor Sons Co. Bulletin 347.

"Gunmix", a new series of refractories designed for rapid emplacement by air stream and water, is described and illustrated. Basic Refractories, Inc. Bulletin 480.

Steel Plant Cement for hot or cold patching of soaking pits, open hearths, electric furnaces, forging furnaces and reheating furnaces is described in new folder by Electro Refractories & Alloys Corp. Bulletin 407.

"Carbofrax" refractory skid rails are described and blueprinted for many types of furnaces in this 20-page booklet by the Carborundum Co. Bulletin 500.

Wesgo super refractory shapes are described in this bulletin. With ability to withstand almost any amount of thermal abuse, these shapes possess high fusing range (up to 3100 deg. F.), low thermal conductivity and complete freedom from impurities such as iron. Western Gold and Platinum Works. Bulletin 526.

FINISHING • PLATING • CLEANING

"Solvent Degreasing" is title of new book showing how to provide the greatest economy in metal cleaning. Detrex Corp. Bulletin 546.

Roto-Finish equipment for deburring, buffing, polishing and coloring. Sturgis Products Co. Bulletin 170.

A protective, deep black finish to steel. Heatbath Corp. Bulletin 171.

Motor-Generators for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin 173.

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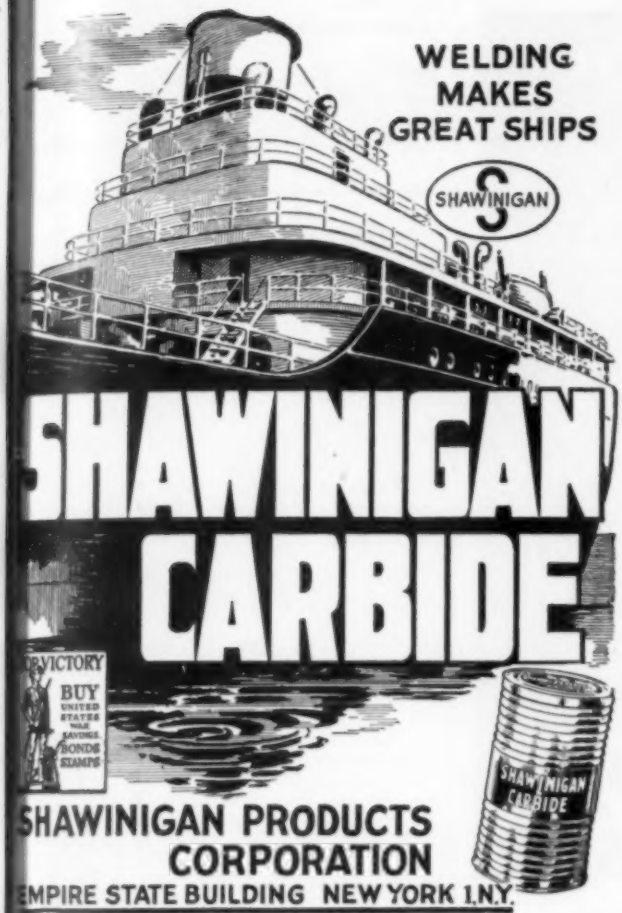
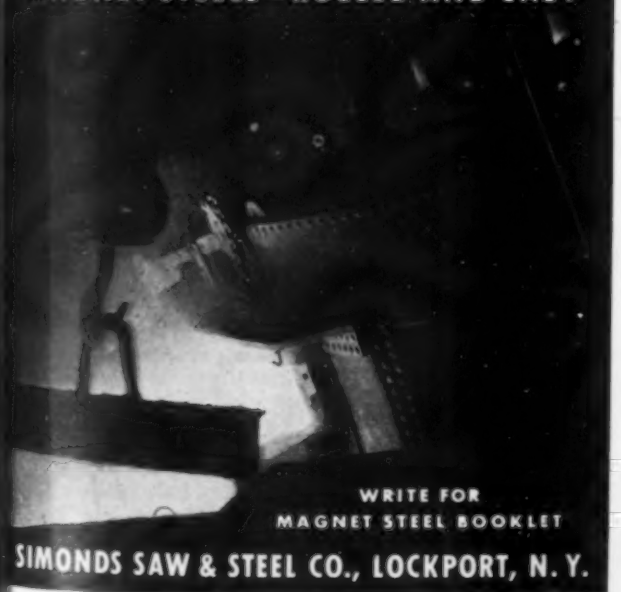


SHAWINIGAN PRODUCTS CORPORATION
EMPIRE STATE BUILDING NEW YORK I.N.Y.

SIMONDS

TOOL, HEAT-RESISTING, HIGH NICKEL ALLOY AND SPECIAL STEELS

MAGNET STEELS—ROLLED AND CAST



WRITE FOR MAGNET STEEL BOOKLET

SIMONDS SAW & STEEL CO., LOCKPORT, N. Y.

Armour's Anhydrous Ammonia

Guaranteed Pure, Dry

For Nitriding and Protective Atmospheres

Over fifty years of experience in servicing thousands of ammonia users assures you that when you order Armour's Anhydrous Ammonia, you get not only a pure, dry, dependable product, but also the best service obtainable.

Take advantage of our technical service by writing us on any problems concerning the use of Anhydrous Ammonia in Nitriding, Dry Cyaniding, or as a protective atmosphere either by itself or in conjunction with other gases.

Prompt delivery in Bottle Type or Tube Type cylinders, 100 lb. and 150 lb. sizes, from one of our plants or nearest of our sixty stock points.

ARMOUR AMMONIA WORKS

Division of Armour and Company

1355 West 31st Street Chicago, Illinois

For free descriptive circular on the proper method of handling and hooking up Anhydrous Ammonia cylinders, please clip and mail the coupon below.

Armour Ammonia Works,
1355 W. 31st St.,
Chicago, Ill.

Please send by return mail a copy of your circular on "Methods of Handling Cylinder Anhydrous Ammonia for Metal Treaters."

Name_____

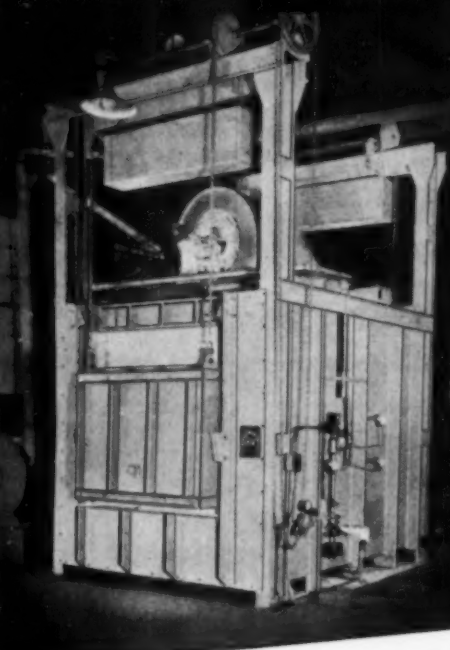
Title_____

Company_____

Street_____

City_____ State_____

It Takes the Best TO MAKE THE BEST



HEAT-TREATED STEEL CASTINGS

Exceptionally close temperature uniformity for work requiring a maximum of 1300° F. is obtained in this small R-S Convection Type Furnace. Large volume air circulation permits rapid heating and high production. Program heating and cooling is also possible on work requiring a slower rate of heating or a definite time-temperature cycle.

Automatic temperature control and combustion safety devices with dependable air circulation and proper distribution assure a continuous flow of uniformly heat-treated material.

If you have an industrial heat treating problem, write on your company letterhead for helpful suggestions.

FURNACE DIVISION

R-S PRODUCTS CORPORATION

128 Berkley Street • Philadelphia 44, Penna.

ANNEALING CONVECTION ROTARY HEARTH SALT BATH FORGING
CONTINUOUS CONVEYOR PLATE AND ANGLE HEATING METAL MELTING CAR HEARTH

R-S Furnaces of Distinction

BUY WAR BONDS

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin 172.

Electrochemical Descaling. Bullard-Dunn Process Div., Bullard Co. Bulletin 212.

Airless Rotoblast. Pangborn Corp. Bulletin 176.

Rust inhibiting wax coatings for protection of metal. S. C. Johnson & Son, Inc. Bulletin 180.

Cadmium Plating. E. I. duPont deNemours & Co., Inc. Bulletin 177.

Tumbling and cleaning. Globe Stamping and Machine Co. Bulletin 179.

Catalog on finishing and cleaning. Frederick Gumm Chemical Co., Inc. Bulletin 292.

"Indium and Indium Plating". Indium Corp. of America. Bulletin 182.

Jetal process and its characteristics as a protective coating. Alrose Chemical Co. Bulletin 213.

Cyanide zinc and bright zinc plating with Turco Type X, Turco Porokleen and Turco Penetrol is described in this 10-page booklet by Turco Products, Inc. Bulletin 495.

Lead plating is discussed in new booklet issued by Harshaw Chemical Co. Bulletin 109.

Service report describes use of Oakite machining, drawing, degreasing and descaling materials. Oakite Products, Inc. Bulletin 210.

Special data sheets on compounds for various cleaning jobs are offered by MacDermid, Inc. Bulletin 436.

Technical bulletin describes materials developed to meet specialized processing and cleaning needs. Kelite Products, Inc. Bulletin 438.

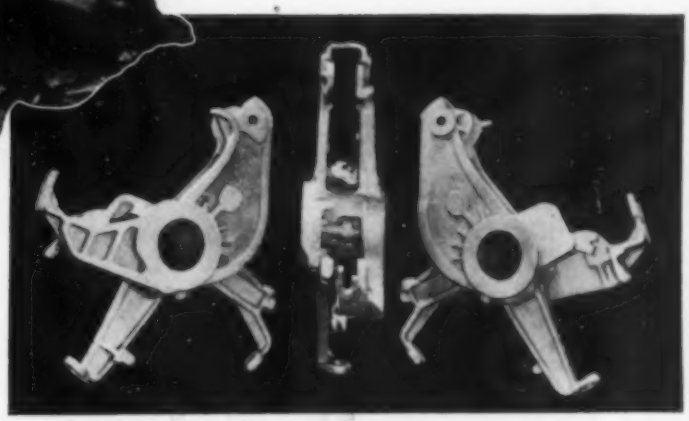
New 1944 catalog describes metal cleaning equipment offered by N. Ransohoff, Inc. Bulletin 439.

"Deoxidine" for a better rust removing and metal cleaning job is described along with several applications in this 4-page leaflet. American Chemical Paint Co. Bulletin 528.

Use Handy Coupon on Page 348 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 348, 350, 352, 354, 356, 358, 360, 364, 366, 368, 374, 378, 380 and 384.

Tomorrow

BETTER PRODUCTS FOR PEACE



. . . Steel Castings

Steel Castings are helping to produce better products, for War and Peace . . . in these product lines ➡

- Aeronautical
- Agricultural Machinery
- Automotive
- Bearing
- Boiler, Tank & Piping
- Bridge
- Chemical & Paint Works
- Compressors (Pneumatic)
- Conveyor & Material Handling
- Crushing Machinery & Cement Mill
- Dredge
- Electrical Machinery & Equipment
- Elevator
- Engine
- Food Processing & Packing Plant
- Foundry Machinery & Equipment
- Gas Producer & Coke Oven
- Gears
- Heat Treating Furnace & Equipment
- Hoist & Derrick
- Iron & Steel Industries
- Metallurgical Machinery
- Mining Machinery & Equipment
- Oil or Gas Field & Refinery
- Ordnance
- Overhead Crane & Charging Machine
- Paper Mill
- Printing Press
- Pump
- Railroad
- Refractory, Brickyard & Ceramic
- Refrigeration Machinery
- Road & Building Construction
- Rubber Mill
- Ship & Marine
- Shoe Machinery
- Smelting Plant
- Spray Painting Equipment
- Steam Turbine
- Street, Elevated & Subway Cars
- Textile Machinery
- Valves, Fittings & Piping
- Well Drilling Equipment

Los Angeles, Calif.
Utility Electric Steel Foundry
3334 East Slauson Ave. Kimball 4185

Tulsa, Oklahoma
Oklahoma Steel Castings Company
1200 N. Peoria. 5-5286

Indianapolis, Indiana
Electric Steel Castings Company
Speedway. Belmont 0400

Houston, Texas
Texas Electric Steel Casting Company
Bringhurst & Gillespie. Fairfax 8117

Buffalo, N. Y.
Strong Steel Foundry Co.
51 Norris St. Riverside 2700

Toledo, Ohio
Unitcast Corporation, Steel Casting Div.
Front and Millard Ave. POntiac 1545

WELDCO

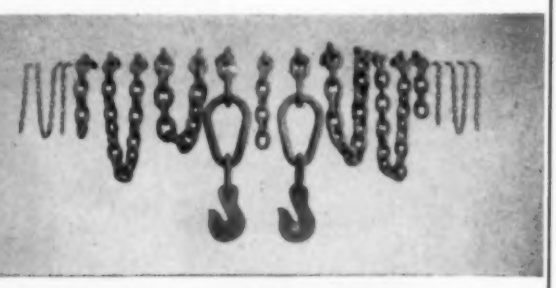
CORROSION RESISTANT CHAIN, HOOKS, AND ACCESSORIES

SAFETY—The uncertain behavior of castings, due to brittleness and non-uniformity, is eliminated by the use of wrought Monel metal for chains, hooks, and accessories. Having great strength and resistance to shock, there is with Monel less chance of failure, caused by a quick lift or shock from a direct blow.

LONGER LIFE—Uniform corrosion resistance coupled with the very unusual combination of high tensile strength and high ductility and toughness, leaves little question as to a Weldco chain's extra life when compared to chain made of other materials.

LIGHT WEIGHT—There's 20% less dead weight for equivalent strength with Weldco, Monel chain.

Weldco catalog on Pickling, Annealing, and Heat Treating contains excellent data on chains. Write for your copy today.



THE YOUNGSTOWN WELDING & ENGINEERING CO.

3722 Oakwood Avenue Youngstown, Ohio

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Three new booklets have been issued by the Enthone Co. describing an acid addition agent, hard drying rust-inhibiting waxes and a new alkali steel cleaner. Bulletin 420.

Several practical data sheets show cleaning methods used on aluminum, brass and steel. Diversey Corp. Bulletin 446.

New 144-page catalog "Chemicals by Glyco" features many tables of useful chemical and physical data. Glyco Products Co., Inc. Bulletin 449.

"Surface-Peening" by shot-blasting to improve the strength of metal parts is described in this leaflet by W. W. Sly Mfg. Co. Bulletin 521.

ENGINEERING • APPLICATIONS • PARTS

Carburizing Boxes. Pressed Steel Co. Bulletin 193.

Heat treating fixtures for pit-type furnaces are shown in new booklet by Driver-Harris Co. Bulletin 363.

Pressed steel pots are described by Bell & Gossett Co. in new Bulletin 364.

Specifications and physical properties of bronze and aluminum alloys are shown in Olds Alloys Co. Bulletin 457.

Chace manganese alloy No. 772 in sheets, strips, rod and special shapes described by W. M. Chace Co. Bulletin 190.

Catalog gives complete specification data on Bunting bearings and bars. Bunting Brass & Bronze Co. Bulletin 343.

New 32-page illustrated booklet contains much data on manganese steel for the railroad industry. American Manganese Steel Div. Bulletin 388.

Illustrated leaflet presents data and uses of special alloys resisting corrosion, high temperatures and abrasion. The Duraloy Co. Bulletin 390.

24-page catalog is guide to properties and use of Monsanto plastics. Monsanto Chemical Co. Bulletin 319.

Use Handy Coupon on Page 348 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 348, 350, 352, 354, 356, 358, 360, 364, 366, 368, 370, 378, 380 and 384.

DURALOY

THE RIGHT ALLOY CASTING MADE RIGHT

REACTION CHAMBER

THE right analysis for the alloy to withstand corrosion, high or sharply varying temperatures or abrasion does not of itself assure castings that will give the enduring service you want.

Foundry work must be right. Castings, annealing, machining, and other fabrication operations, where required, must be right, too. A pioneer in the high alloy casting field, the Duraloy Company has grown through doing all these things right.

The Duraloy Company has unexcelled facilities for founding, annealing, machining, and fabrication work. Consult us on your casting requirements; we shall be glad to aid in determining the best analysis and all successive steps.

FEED SPOUTS

THE DURALOY COMPANY

Office and Plant: Scottdale, Pa.

Eastern Office: 12 East 41st St., New York 17, N. Y.

Los Angeles & San Francisco: Kibby & Graham

Chicago & Detroit: F. B. Cornell & Associates

Scranton, Pa.: Coffin & Smith

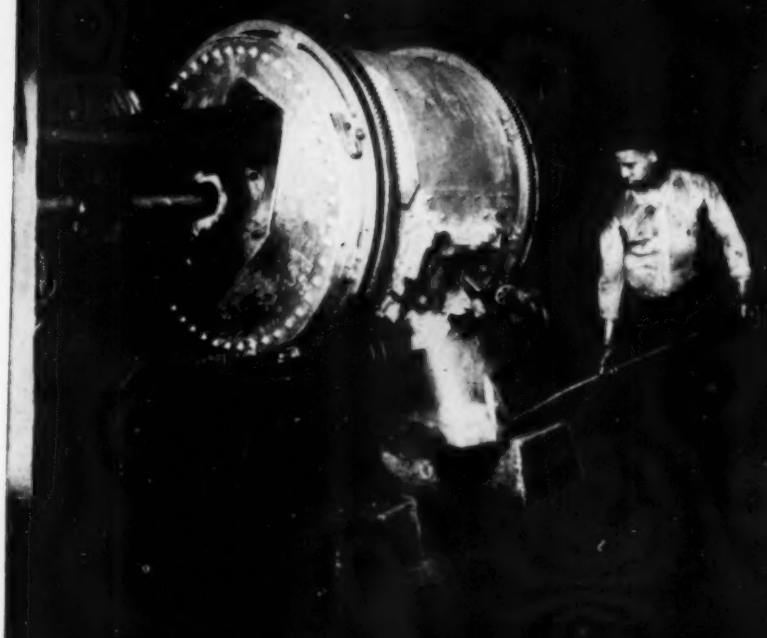
METAL GOODS CORP.: ST. LOUIS • HOUSTON • DALLAS • TULSA • NEW ORLEANS • KANSAS CITY

8-DU-2

"Our metal losses run between .4% and .5% with a Detroit Rocking Electric Furnace"

A Foundry producing intricate bronze parts with a Detroit Rocking Electric Furnace Wrote recently, "Our principal alloy is 78-79% copper 2½% tin, 10% lead, 8-9% zinc, 0.5% nickel. Tests consistently showed the metal losses during melting run between .4% and .5%."

Records in scores of foundries show similar low metal losses and many other advantages. Detroit Electric Furnaces require less labor and produce more pounds of perfect castings per man-hour. They produce as many as 8 ferrous or 16 non-ferrous heats in one eight-hour day. Because they allow precise metallurgical control of any formula, Detroit Furnaces assure superior metallurgical results. Built in capacities from 10 to 8,000 lbs. Write today for further facts.



DETROIT ELECTRIC FURNACE DIVISION
KUHLMAN ELECTRIC COMPANY • BAY CITY, MICHIGAN

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

New information sheets on tapered and formed tubes have just been issued by Summerill Tubing Co. Bulletin 369.

54-page booklet, "File 41 — Engineering Data Sheets", gives complete facts on Ampco Metal's physical properties and service record. Bulletin 368.

Many applications and savings through use of drop forgings are shown in Drop Forging Topics, issued by Drop Forging Assn. Bulletin 240.

Details of new Chemicast process for small brass parts will be supplied by Chemicast Div., Whip-Mix Corp. Bulletin 330.

Electrical, corrosion and heat resisting alloys in rod, wire, ribbon and strip forms. Wilbur B. Driver Co. Bulletin 192.

Reference data book entitled "The Improvement of Metals by Forging" has been issued by Steel Improvement & Forge Co. Bulletin 409.

Interesting and informative literature on "Pomet" powder metallurgy products. Powder Metallurgy Corp. Bulletin 454.

Industrial applications of National and Karbate carbon and graphite products are illustrated in 16-page booklet issued by National Carbon Co., Inc. Bulletin 426.

X-Ray Inspected Castings. Electro Alloys Co. Bulletin 197.

Steel Castings. Chicago Steel Foundry Co. Bulletin 199.

Heat Resisting Alloys. General Alloys Co. Bulletin 200.

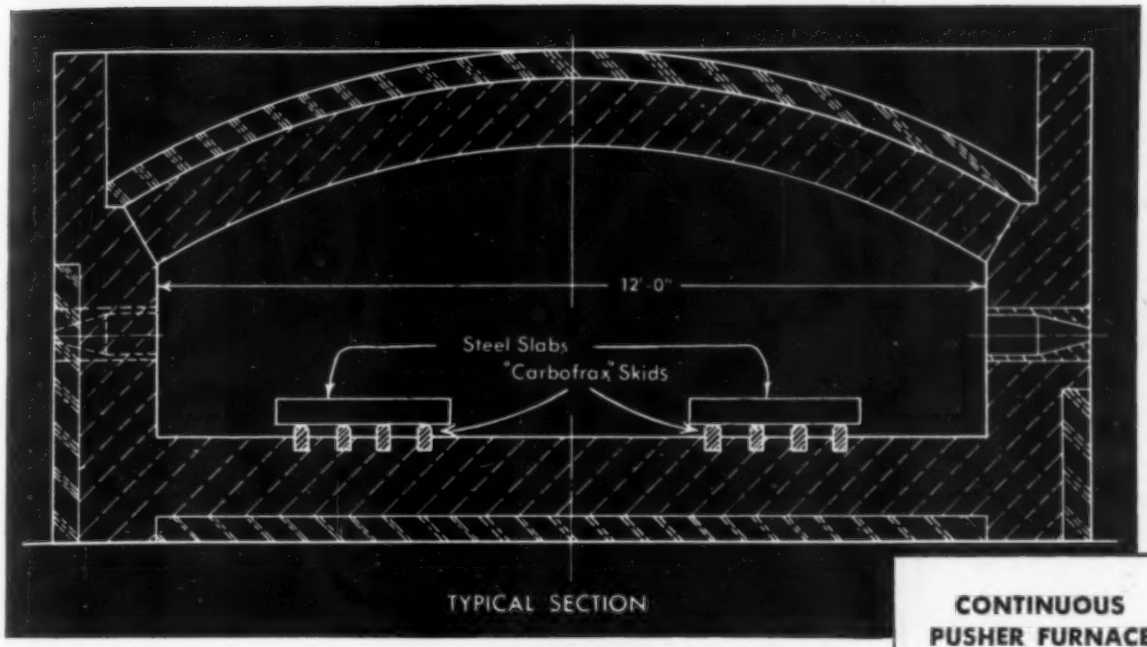
Pipes and Tubes. Michigan Steel Casting Co. Bulletin 201.

Cr-Ni-Mo Steels. A Finkl & Sons Co. Bulletin 203.

Industrial baskets, crates, trays and fixtures. Rolock, Inc. Bulletin 204.

Handsome 12-page brochure pictures the cast steel breech rings and their advantages as produced by the Ohio Steel Foundry Co. Bulletin 515.

Use Handy Coupon on Page 348 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 348, 350, 352, 354, 356, 358, 360, 364, 366, 368, 370, 374, 380 and 384.



CONTINUOUS PUSHER FURNACE

Handling steel slabs up to 5½" x 30" x 69" and weighing up to 3,000 pounds each.

Hearth dimensions: 12' Wide, 40' Long.

Operating Temperature: 2000°—2100°F.

8 Rows of "Carbofrax" Skid Rails (Unit size 2½"x4½"x18")

ONCE AGAIN

HELP BOOST PRODUCTION!

WHEN uncooled alloy rails were used in this furnace, they warped so badly after only a few days' operation that frequent shutdowns for skid maintenance were necessary. Production was curtailed. Repair and replacement costs were excessive.

Switching to "Carbofrax" Skid Rails, the operators found that these refractory shapes almost completely eliminated rail maintenance. Moreover, an average life of seven months was obtained from the "Carbofrax" skids.

Because of their longer life—with practically no time out for repairs—the use of "Carbofrax" Skid Rails in this plant has increased production and markedly lowered maintenance expense. Add to this the lower initial cost, and you can readily realize why more and more operators are switching from alloy rails to "Carbofrax."

Make a note now to call in one of our Refractories Engineers and have him explain how "Carbofrax" Skid Rails can be applied to your heating furnaces. You, too, can secure these same advantages.

THE CARBORUNDUM COMPANY
Refractories Division, Perth Amboy, N. J.

District Sales Branches: Chicago, Philadelphia, Detroit, Cleveland, Boston, Pittsburgh.

Distributors: McConnell Sales & Engineering Corp., Birmingham, Ala.; Christy Firebrick Company, St. Louis, Mo.; Harrison & Company, Salt Lake City, Utah; Pacific Abrasive Supply Company, Los Angeles & San Francisco, California; Denver Fire Clay Company, El Paso, Texas; Smith-Sharpe Company, Minneapolis, Minn.

"Carborundum" and "Carbofrax" are registered trade-marks of, and indicate manufacture by, The Carborundum Company

Super Refractories by CARBORUNDUM
TRADE MARK

SEND FOR *this free booklet and learn how "Carbofrax" Skid Rails can be used to minimize problems in a wide variety of heating furnaces.*

The Carborundum Company, Perth Amboy, N. J.
I'd like a copy of your booklet on "Carbofrax" Skid Rails.

Name _____
Title _____
Company _____
Address _____
City _____ State _____

Reduced Rejections Reduce Costs!

SPEED CASE STEEL

A LOW CARBON OPEN HEARTH PRODUCT..

IMPROVED QUALITY

- Rivets Without Fracture
- Smooth Finished Parts
- Increased Machinability

Excellent Ductility

This hub, for a V Type Metal Pulley, was machined faster than Bessemer B 1112 Steel. The flange for holding the stampings was riveted over without any sign of fracture.

Speed Case replaced X 1314 and increased production at least 25%.

Estimated savings per ton of Speed Case used were $41.35.

Write for SPEED CASE CATALOG showing savings of 20 to 65%.

If you wrote your own specifications for the ideal, all purpose, open hearth carburizing STEEL, it would be . . . SPEED CASE!

BUY WAR BONDS

Licensor

MONARCH STEEL COMPANY

HAMMOND · INDIANAPOLIS · CHICAGO

Licensee for Eastern States

THE FITZSIMONS COMPANY

YOUNGSTOWN, OHIO

PECKOVER'S LTD., Toronto, Canadian Distributor

MANUFACTURERS OF COLD FINISHED CARBON AND ALLOY STEEL BARS

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

"Mechanical Springs, **Their Engineering and Design" is the title of a 106-page handbook just issued jointly by the divisions of Associated Spring Corporation. Bulletin 481.**

Many types of heat treating **and pickling baskets and containers are shown in new booklet by the Stanwood Corp. Bulletin 445.**

Complete line of Mallory **radio, electrical and electronic parts, with sizes, dimensions and rated capacities is described in new 36-page booklet. P. R. Mallory & Co., Inc. Bulletin 448.**

The Wilco Blue Book **deals with the 29 Wilco Thermometals, their properties, functions, applications and temperature ranges. H. A. Wilson Co. Bulletin 531.**

Illustrated leaflet **describes stainless steel castings by Atlas Foundry Co. Bulletin 437.**

Illustrating **several heat resistant alloy applications, this 4-page leaflet cites four factors essential to efficient alloy use. Sterling Alloys, Inc. Bulletin 504.**

Cooper standard alloys. **Cooper Alloy Foundry Co. Bulletin 206.**

Three-color chart **of decimal equivalents. John Hassall, Inc. Bulletin 458.**

Drop, hammer and upset forgings. **Kropp Forge Co. Bulletin 534.**

Steel Forgings. **Transue and Williams Steel Forging Co. Bulletin 535.**

Specifications and diagrams **are included in description of welded rings and bands. American Welding & Mfg. Co. Bulletin 536.**

MELTING • CASTING • MILL OPERATIONS

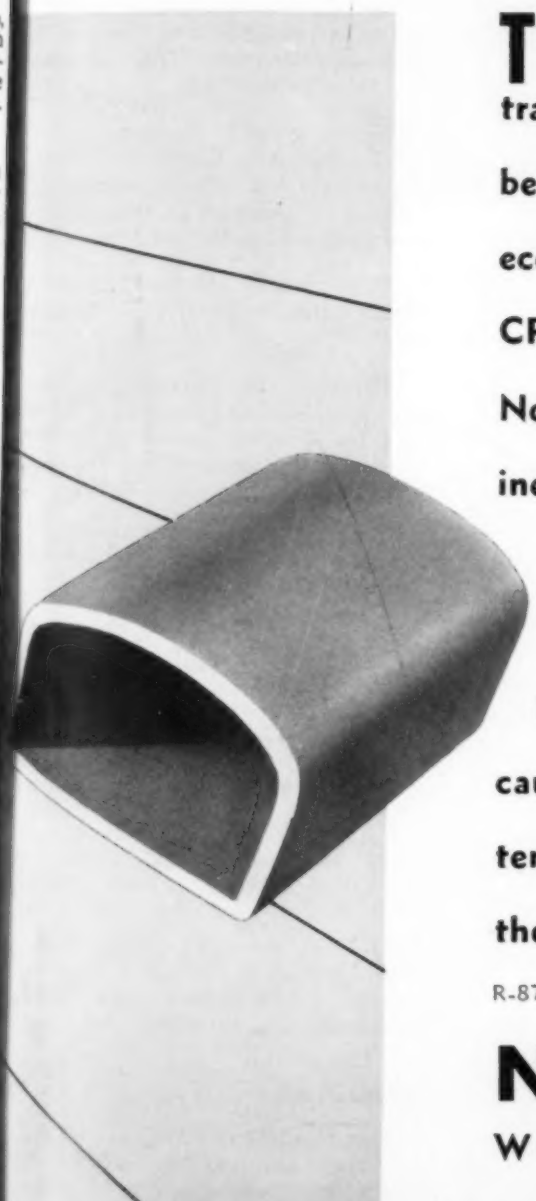
Ingot Production. **Gathmann Engineering Co. Bulletin 185.**

Electric Furnaces. **Detroit Electric Furnace Div., Kuhlman Electric Co. Bulletin 189.**

Use Handy Coupon on Page 348 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 348, 350, 352, 354, 356, 358, 360, 364, 366, 368, 370, 374, 378 and 384.

NORTON REFRACTORY MUFFLES



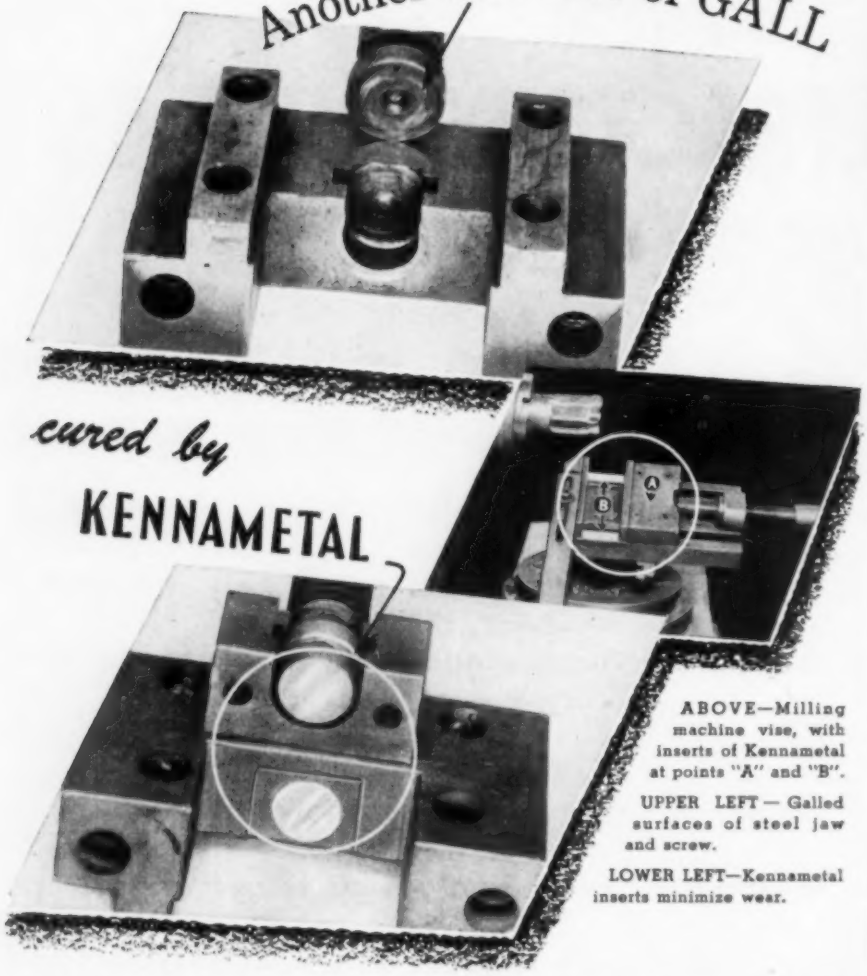
THE ability of Norton Refractory Muffles to transfer heat readily allows furnace and work to be brought up to temperature quickly and assures economical furnace operation. Available in both CRYSTOLON (SiC) and ALUNDUM (Al_2O_3) Norton muffles are highly refractory, chemically inert under exceedingly high temperatures, and physically rugged. Both CRYSTOLON and ALUNDUM muffles are suited for electric furnaces — although ALUNDUM cement, because of its higher electrical resistance at elevated temperatures, is generally used for embedding the resistor wire.

R-871

NORTON COMPANY
WORCESTER 6, MASSACHUSETTS

Norton Longer Lasting Refractories

Another bad case of GALL cured by KENNAMETAL



ABOVE—Milling machine vise, with inserts of Kennametal at points "A" and "B".

UPPER LEFT — Galled surfaces of steel jaw and screw.

LOWER LEFT—Kennametal inserts minimize wear.

The superiority of Kennametal for wear-resistant purposes is graphicly demonstrated in this milling machine vise. The steel parts of the jaw and screw (enclosed in box "A") wore and tore under the twisting force exerted by the clamping mechanism. Thin discs of Kennametal—one brazed to the end of the screw, another recessed into the jaw at the abutting point—permit the jaw to be closed securely, and opened readily, with less effort. The performance of the vise has been further improved by inserts of Kennametal in the sliding surfaces on which the work rests, at points marked "B".

The high hardness of Kennametal (78 Rockwell C), and its unique non-galling property, provide resistance to abrasive wear that is up to 100 times that of steel. Kennametal's modulus of elasticity—2 to 3 times that of steel—minimizes possibility of deformation. Its unusual dimensional stability makes creep negligible.

Kennametal is available in a variety of standard shapes, or it can be furnished molded into almost any special form, limited only by reasonable proportions. We have supplied Kennametal . . . as accurately molded inserts for the customer to apply and grind as desired . . . mounted on parts furnished to us, and then finished by the customer or by us . . . embodied in elements or devices produced complete in our plant.

You can readily, and economically, incorporate Kennametal in the wear-areas of the machines you use, and the products you manufacture. Tell us your problem. We will suggest how Kennametal can solve it.

KENNAMETAL
SUPERIOR CEMENTED CARBIDES
KENNAMETAL Inc., LATROBE, PA

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

8-page illustrated booklet describes crucible melting furnaces for brass, bronze, aluminum, copper and other alloys. Stroman Furnace & Engineering Co. Bulletin 473.

Crucibles for brass, copper, aluminum and magnesium industries. Electro Refractories and Alloys Corp. Bulletin 183.

This ring-binder presents 24 pages on the use and effect of Titanium in steel and cast irons. Titanium Alloy Mfg. Co. Bulletin 470.

52-page booklet describes Moore rapid Lectromelt furnaces for iron, steel, nickel and copper melting and refining. Pittsburgh Lectromelt Furnace Corp. Bulletin 404.

"Electromet Products and Service". Electro Metallurgical Co. Bulletin 186.

Interesting and helpful information available on the use of alloy pots for heating operation by the Swedish Crucible Steel Co. Bulletin 137.

Operating Features, capacities, charging methods of the Heroult electric furnace. American Bridge Co. Bulletin 215.

"Fisher Magnesium Scrapbook". Fisher Furnace Co. Bulletin 281.

Attractive booklet describes growth, facilities and offers valuable alloy hints. Niagara Falls Smelting & Refining Corp. Bulletin 246.

Interesting, descriptive leaflet on metal reclaiming mill offered by Dreisbach Engineering Corp. Bulletin 284.

Foundry ovens for core baking, mold drying and pasting are illustrated in new 4-page leaflet by Despatch Oven Co. Bulletin 510.

GENERAL

New leaflet describes interoffice communication system offered by Executone Communication Systems. Bulletin 385.

Use Handy Coupon on Page 348 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 348, 350, 352, 354, 358, 360, 364, 366, 368, 370, 374, 376, 378 and 380.